GREENNESS AND RESILIENCE TO SOCIAL AND BUILT ENVIRONMENTAL STRESS

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ABSTRACT

Background: Urbanization and emissions of carbon dioxide are increasing the risk of abnormally high ambient temperatures, and the associated risks of violence and other heat related stressors. These stressors affect physiologic hormonal mechanisms in the body. Vegetation serves the ecosystem through photosynthesis and transpiration, including sequestration of carbon dioxide and reducing ground level temperatures. The non-material benefits of vegetation may increase physiologic resilience of individuals and communities to stressful social and built environments and mitigate causes of that stress, such as violence.

Purpose: To examine the effect of greenness on stress and resilience to stress among African American women, ages 18-44 in Baltimore, Maryland framed within an adaptation of the Szanton and Gill *Society-to Cells Resilience Model*.

Design and Methods: This mixed methods study modeled the relationship between greenness of chlorophyll from satellite mapping and the ratio of cortisol and dehydroepiandrosterone within the social and built environment among African American women between the ages of 18-44 (n=98), who were at high risk of HIV and live in a mid-Atlantic city of the United States. Covariates included sexual violence, crime, vacant property, traffic proximity, education, income, perceived stress and unprotected sex partners. We also utilized the analysis of interviews with key informants (n=10), observational field notes, historical records and images to understand the resilience potential of key communities within the highest and lowest quintile of the sample.

Results: Multi-level analysis at the community statistical areas (n=55) revealed that one standard deviation (0.039) increase in greenness was associated with a 34% increase (β= 7.5, $p<.05$) in physiological-resilience (operationalized as the ratio of cortisol to dehydroepiandrosterone), adjusting for experience of sexual violence (none, adult only, or adult & childhood), unprotected sex partners, perceived stress, income, education, population adjusted crime, traffic proximity and vacant property. The analysis of qualitative data revealed that, according to key informants, green spaces have the ability to promote feelings of calmness. However, access to green spaces is restricted when traveling through social and built environments that are perceived as unsafe or unpleasant, potentially discouraging use.

Conclusion: As demonstrated by this research, the capability of green spaces to support the resilience potential of African American women and their communities would benefit from increased collaboration between community organizations and other stake holders, including government, healthcare systems and other institutions.

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CHAPTER ONE: INTRODUCTION

Urban-dwelling African American women increasingly experience threats to their health and wellbeing through the complex intersection of social and built environmental stress. These stressors include violence (Perry, Harp, & Oser, 2013), access to ecosystem services (Jesdale, Morello-Frosch, & Cushing, 2013) that mitigate the health effects of noise pollution (Dzhambov & Dimitrova, 2014), air pollution (Olden, 1996; Pratt, Vadali, Kvale & Elickson, 2015) and extreme weather events, including heat-related illnesses (Petkova et al., 2014). From 2002 to 2009 the estimated health care cost of climate change in the United States of America (US) was $84.3 million, in 2017 U.S. dollars (Knowlton, 2011). This estimate only examined six of the ten (Portier et.al, 2010) health affecting environmental changes from climate change: ozone smog pollution, heat wave, hurricane, wildfire, mosquito borne disease and river flooding (Knowlton, 2011). Other known health affecting environmental changes are: (1) increases in ambient temperatures (additional vector borne and zoonotic diseases, **aggression, crime,** food production, decreased plant nutrient value and increased food toxins), (2) increased risk of droughts (displacement, **conflict**, concentration of waterborne pathogens, decreased agricultural productivity), (3) sea level rise (displacement, **conflict**) and (4) ocean acidification (availability of food, coral reef storm surge protection loss) (Portier et.al, 2010).

The urban heat island effect stems from concentrated areas of concrete, asphalt, brick and stone that contribute to higher temperatures as compared to areas with more vegetation (US EPA, 2014). The energy from the sun is absorbed by concrete, asphalt, brick and stone and is radiated back into the air, increasing ambient temperatures throughout the day and night, whereas vegetation, especially trees, decrease ground level temperatures (Livesley, McPherson, & Calfapietra, 2016; McPherson, Simpson, Peper, Maco & Xiao, 2005). To lessen the heat island effect, evidence-based interventions are needed to mitigate the causes of abnormally warm temperatures and their impact on the health and wellbeing of individuals and their families. Plant carbon dioxide (CO_2) sequestration is one method of mitigating the causes of climate change (National Research Council, 2015). Plant based CO_2 sequestration has the co-benefit in urban environments of facilitating adaptation by the shading of heat absorbing materials (concreate and asphalt), and through plant transpiration (Livesley et al., 2016). Transpiration is a process where plants and trees pull water from the ground and into their roots, then out through the leaves and into the air, reducing temperature around the tree. In urban areas, green spaces' ability to sequester CO_2 and reduce the urban heat island effect is significant, given the mediation ($p<.05$) of positive associations between raising average temperatures and aggressive behaviors over time ($\beta = 0.23$, 95% CI: 0.00, 0.46; $\beta = 0.35$, 95% CI: 0.06, 0.63; $\beta = 0.41$, 95% CI: 0.08, 0.74) (Younan, et al., 2018). This association is even more important given predictions of increases in violent crime related to climate change by 3% (95%CI, 1.5-5.4) by the end of the century, based on predicted changes in global CO_2 emissions with a median probability (Hsiang, Kopp, & Jina, 2017). In 2011, the economic costs of violence worldwide were over $10.5 trillion (2018 dollars), 98% of it from interpersonal violence and intimate partner violence (Hoeffler, 2017). A three percent increase in violence associated with climate change could account for an additional $316 billion in costs by 2050, not accounting for inflation.

Increased cortisol is positively associated with exposure to heat-stress ($r=0.57$, $p<.001$) (Mazlmoi et al., 2017) and recent experiences of violence (Heller et al., 2018). The presence of environments that promote a healthy stress response may boost both individual and community resilience to the increasing heat related impacts of climate change (Levene & Conversi, 2014). Resilience is defined as the capacity of an individual or community to prepare for, avoid and adapt to negative social, psychological, and biological consequences of extreme stress or shocks that would otherwise compromise their wellbeing (Szanton & Gill, 2010). Yet resilience has seldom been used to refer to community and environmental processes (Petros, Opacka-Juffry, & Huber, 2013; Szanton & Gill, 2010). Both individual and community resilience are needed to mitigate the causes of climate change, adapt urban environments to increases in the associated violence (Mares, 2013), and reduce the body's chronic stress response (Gallagher, Sumner, Muldoon, Creavan, & Hannigan, 2016).

Significance

It has been proposed that humans have changed the environment to a degree that the planet Earth has entered a new epoch, the Anthropocene (Whitemee et al., 2015). Human activities have so impacted our planet, the one we call home, that the very geological systems that support our health and our civilization are being changed to a point that the health of the most vulnerable is suffering (Millennium Ecosystem Assessment, 2005).

Morbidity, mortality, and extinction are part of the evolutionary story, but they are happening at increasing and alarming rates (Millennium Ecosystem Assessment, 2005). The home for two thirds of the earths organisms and the most biologically diverse ecosystems on the planet are tropical rainforests (National Research Council, 1998). Tropical forests have described as the lungs and heart of the planet, for its significant capacity to "inhale" carbon dioxide, "exhale" oxygen and move water and heat to the rest of the planet (Trivedi et al, 2009). Forest ecosystems are under ongoing land use changes that threaten potential tipping points in the ability of the forest to naturally recover (Nepstad, Stickler, Soares-Filho & Merry, 2008). Since the dawn of agriculture, 34-53% of tropical forests have been lost, 54-60% of subtropical, 48% of temperate, and 19% of boreal forests (Sandker, Finegold, D'Annuzio, & Lindquist, 2017). Between 1990 and 2005, the planet lost 7.1% of tropical, 4% of subtropical, 1.6% of temperate and 1.2% of boreal forests (Sandker et al., 2017). In addition to oxygen, forests (including trees, plants and other biomes) provide shelter, food and habitat for the multitude of species that inhabit the earth.

The desertification and urbanization of these spaces stresses the ability of species, including homo sapiens, to gather food, find shelter and interact (National Research Council, 1998). Urban environments once were estimated to cover about 3% of the Earth's surface (Balk, 2004). In 2008, urban environments covered 3.5 million km^2, and are estimated to increase to 12.5 million km^2 by 2030 (Seto, Fragkias, Güneralp, & Reilley, 2011). Concrete and asphalt are barriers to human access to ecosystems services, including cultural services, provided by biologically diverse environments, especially seen among the most vulnerable (Jesdale et al., 2013).

Human health and civilization is dependent on food, shelter, clean air, water and safe places to play (Millennium Ecosystem Assessment, 2005). Humans living in urban spaces that lack biological diversity risk shortage in cultural services of ecosystems, the intangible services of "spiritual enrichment, cognitive development, recreation, and aesthetic experiences" that the planet provides (Milcu, Hanspach, Abson, & Fischer, 2013; Millennium Ecosystem Assessment, 2005; Tengberg et al., 2012). Cultural services of biologically diverse ecosystems promote leisure, the opportunity to play and relax.

The urban built environment can be hostile to humans, especially as global temperatures rise (National Research Council, 2018). Urban heat island effect, the absorption of solar thermal energy by concrete and asphalt, increases the ambient temperature, and stores heat throughout the day releasing it at night, maintaining elevated temperatures (US EPA, 2014). The physiological result of the urban heat island effect impacts people in different ways: increasing the general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality (US EPA, 2014). Trees provide shade and evapotranspiration, mitigating the impacts of the urban heat island effect on human health (Founda Santamouris, 2017). Tree shade decreases the amount of thermal energy from the sun absorbed by concreate, asphalt and other surfaces (Napoli, Massetti, Bandani, Petralli, & Orlandini, 2016; Zhao, Yang, Wang, & Wentz, 2018). In combination with evapotranspiration, trees can cool the air and ground level temperatures as much as 4°C (Wang & Akbari, 2016). Cooler ground surface temperatures and tree shade may also prove to mitigate violence associated with increased abnormally high temperatures (Mares, 2013).

Theoretical perspective

The social environment is described as people's perception in a given space, and that determines the way we behave within that physical or built environment (National Research Council, 2013). Historical and present-day unconscious bias are central to the evolution of the built environment, but the impact on health and civilization is tangible

(Grove et al., 2018; Jesdale et al., 2013; Power, 1983). Human health and our civilization is dependent on cellular, physiological, individual, familial, communal and societal resilience to the stress of our environment, including the built and social environments (Szanton & Gill, 2010). The built and social environment are limited in their capacity to support human health by planetary boundaries (Millennium Ecosystem Assessment, 2005). Planetary Resilience thereby is the resilient potential of the planet to continue providing ecosystem services that (human) life, health and civilization depend on. The resilient potential of the planet has developed over millions of years (National Research Council, 2011), and in the past 300 years, humans have consumed vast finite resources that are invaluable for human survival (Demaio & Rockstrom, 2015). For the survival of homo sapiens, for future generations, and for all the species we co-depend in this planet, we must advance our civilization toward one that promotes resilience (cellular to planetary), with special attention to the urban built and social environments, where more than 54% of the world population live (UN, 2014).

Model

The mechanism of the effect of greenness on health and resilience of individuals and communities to stress from social and built environmental violence is not fully understood. Potential pathways and mechanisms of greenness that influence physical and psychological states and behavioral conditions include mitigation of noise pollution and heat, mental fatigue reduction through passive engagement from natural sounds and sights, and creation of spaces for social interaction and physical activity (James, Hart, Banay, & Laden, 2016; Kuo, 2015) (see Figure 1). From this we built our conceptual framework of the relationship of greenness with physiological resilience adapting the

Szanton and Gill *Society-to Cells Resilience Model* (see Figure 2). This theory is a descriptive middle range theory, based on the multiple factors of resilience. This model proposes that each person is born with resilient potential and this potential changes over time depending on interactions between society, community, family, psychological, physiologic and cellular factors, and how each factor reacts to a challenge (Szanton & Gill, 2011). The society level of this theory includes Safety in Environment, Race, Educational and Career Opportunities, Gender and the Natural Ecosystem. The community level includes “Diversity,” “Institution,” “Social Support,” “Social Capital,” and the “Built Environment”. The Physiological level includes “Inflammation,” neurochemical activity,” Glucose Regulation,” “Brain Function”, and “Hormone Balance“ guided by the Szanton and Gill conceptualization of resilience we adapted and re-conceptualized Hormonal Balance in Figure 2 as Resilience in the Conceptual Model for this dissertation.

Greenness

Green spaces are essential to human life, both in urban and rural environments. We interact with green spaces and depend on them too. We walk our dogs, relax, jog, have picnics, play sports, grow food and use these natural resources. The greenness of trees and other plants can be remotely measured from space via satellites. By comparing the difference between near infrared (NIR) and visible red (RED) wavelengths of light greenness can be measured and is known as normalized difference in vegetation index (NDVI). The use of NDVI is a validated calculation (NDVI=(NIR-RED)/(NIR+RED)) of the amount of chlorophyll producing plants as part of the natural ecosystem (Rhew, Vander Stoep, Kearney, Smith, & Dunbar, 2011). This measure (referred to as greenness) is an understudied area, especially in the health sciences. Greenness has recently been associated with decreased health impacts from climate change, including physiological (e.g., respiratory illness and heat-related illness (Bottaclico et al., 2016, Kundo & Stone, 2014, Olden, 1996; Petkova et al., 2014) and psychological (e.g., depression and stress) health impacts (Portier et al., 2010; Watts, 2017). Greenness has also been associated with resilient mental health among a representative probability sample of Wisconsin residents (85% non-Hispanic white), and among children living with poverty (ages 3-5) (Flouri, Midouhas, & Joshi, 2014).

Exposure to higher levels of greenness has been associated with lower incidence of cardiovascular disease (Li et al., 2011), respiratory illness, liver cancer, kidney disease (James et al., 2016), and lower rates of violence and crime (Bogar & Beyer, 2016; Garvin, Carnnuscio, Branas, 2013). Furthermore, greenness has been linked to increased physical activity (de vries, van Dillen, Groenewegen, & Spereuwenberg, 2013; Jongeneel-Grimen, Droomers, Van Oers, Stronks, & Kunst, 2014; Lopston, 2012), decreased obesity (Lovasi et al., 2013; Suglia et al., 2016), improved birth outcomes (Hystad et al., 2014; Kihal-Talantikete et al., 2013), decreased urban heat islands (Zhang, Wu & Chen, 2010) and its effect on heat related illness (Chuang, & Gober, 2015), and decreased air pollution (Bottaclico et al., 2016; Olden, 1996). These health conditions and outcomes associated with greenness are also areas of health inequities between African Americans and white Americans (Perry, Harp, Oser, 2013).

Despite some initial studies finding an association between greenness and resilience (e.g., mental wellbeing) among children and non-Hispanic whites (Beyer et al., 2014; Chawla, Keena, Pevec, & Stanley, 2014; Flour, Midouhas, & Joshi, 2014;

Marcelle, 2013), little is known about the impact of greenness on emotional and physiological resilience within the context of the built and social environment of African American women who live in urban neighborhoods. Potential biomarkers of physiological resilience are cortisol and dehydroepiandrosterone (DHEA) (Petros, et al., 2013; Walker, Pfingst, Carnevali, Sgoifo, & Nalivaiko, 2017). Exposure to higher levels of greenness has been associated with lower levels of cortisol (Roe et al., 2013) and allostatic load, and positively associated with DHEA (Egorov et.al, 2017). Research on physiological resilience, or the body's ability to physiologically adapt to stress, including maintaining allostasis (Gill, Vythilingam, & Page, 2008; Petros et al, 2013; Russo et al., 2012), suggests that DHEA has immuno-modulatory effects on the cortisol response to stress (Petros et al., 2013, Gill et al., 2008). For instance, DHEA released in the zona reticularis of the adrenal gland is an antagonist of the immune suppressive activities of cortisol (released in the cortex of the adrenal gland) and helps to counteract the effect of high cortisol from stress (Blum et al., 2013; Bremner, Vermetten, & Kelley, 2007).

Urban amenities, including parks, green spaces, street trees and urban vegetation that provide ecosystem services currently are inequitably distributed, where African Americans are twice (epp=2.31, (95% CI 2.09, 2.55) as likely to live on streets with no tree canopy, and at least 50% impervious surfaces (Jesdale, Morello-Frosch, & Cushing, 2013). Interventions to increase the amount of vegetation, including street trees, parks and other green spaces disproportionately benefited areas with higher incomes and levels or income (Watkins, Mincey, Vogt, & Sweeny, 2017) and potentially contribute environmental gentrification (Checker, 2016; Pearsal & Anugelovski, 2016). Environmental gentrification or green gentrification, is the potential consequence of urban greening that plows through neighborhoods, rather than nurturing the resilience of whole community.

Resilience

Physiological resilience is the body's ability to physiologically adapt to stress, (Petros et al., 2013; Russo et al., 2012; Szanton & Gill, 2010). The physiological resistance to stress is a complex interaction among systems that support allostasis (Egorov et al., 2017; Rogosch, Dackis, & Cicchetti, 2011). Allostasis is the synergism of mechanisms responding to changes in the internal and external environment of the organism (Ramsay & Woods, 2014). One of the systems supporting allostasis is the hypothalamic-pituitary-adrenal axis and the hippocampus (Fries, Dettenborn, & Kirschbaum, 2009). The hypothalamic-pituitary-adrenal axis stimulates the release of cortisol in the adrenal cortex throughout the day (Saczawa, Graber, Brooks-Gun, & Warren, 2013). The hypothalamus releases corticotrophin-releasing hormone, which in turn stimulates the pituitary gland to release adrenocorticotropic hormone. The adrenocorticotropic hormone stimulates the adrenal glands to release glucocorticoids, including cortisol (Phillips et al., 2006). It is hypothesized that just prior to waking up, the hippocampus stimulates the hypothalamus to releases corticotrophin-releasing hormone (Fries et al., 2009). Inversely, as stress on the physiology increases, the load on the systems supporting allostasis lose their ability to respond, resulting in an allostatic load detrimental to health and wellbeing (Egorov et al, 2017; Rogosch et al., 2011).

The ratio of cortisol and DHEA has been suggested as a potential biological marker of physiological resilience (Petros et al, 2013; Prall, Larson & Muehlenbeing, 2017; Walker et al., 2017) and will be operationalized this way for this dissertation (see

Figure 2). Jiang et al., found non-significant (p=.216) differences in the ratio of cortisol to DHEA among college age students (18-26 years old) with depression disorder (x=4.94 [4.1,5.7]) compared to the control group ($\bar{x}$=5.2 [3.9,6.3]) (2017). Prall & Muehlenbein (2015), found that the pre-stress ratio of cortisol (4.69 nmol/L) to DHEA (0.68 nmol/L) was 7:1, while the post-stress ratio of cortisol (7.17 nmol/L) to DHEA (1.227 nmol/L) was 6:1. After 10 minutes, cortisol raised (9.9 nnmol/L) and DHEA plateaued (1.221 nmol/L), giving a ratio of 8:1. At post-stress +20 minutes, cortisol levels stayed elevated (9.9 nmol/L) and DHEA dropped (1.095 nmol/L), giving a ratio of 9:1. At the same time, the sulfate of DHEA (DHEA-S) (22 nmol/L) had a pre-stress ratio to cortisol of 1:5 (Prall & Muehlenbeing, 2015). Dehydroepiandrosterone Suflate (DHEA-S) is a metabolite of DHEA and potentially part of the protective mechanism of DHEA (Prough, Clark, & Klinge, 2016).

Despite some initial findings of an association between greenness and resilience (e.g., mental wellbeing) among children and non-Hispanic whites to stress (Bogary & Beyer, 2016; Chawla et al., 2014; Flouri et al. 2014; Marselle, 2013), little is known about the impact of greenness on emotional and physiological resilience within the context of the built and social environment of African American women.

Built Environment

The built environment is the space where people work, live and play, including roads and traffic density, houses and vacant properties (Garvin, 2013, Tachikawa & Hashimoto, 2007). In 2016, sixty percent of Baltimore City residents drove alone to work (Baltimore Neighborhood Indicators Alliance, 2016). An additional 217,235 people commute from surrounding counties and states into the city to work (Maryland State

Government, 2018). All this traffic contributes to noise pollution (Brown, 2015). Casey et al., (2017) found non-significant differences in mean ambient human caused noise pollution, with the highest decibel levels among the lowest income quartile block groups ($\bar{x}$=47.6, 95% CI 47.3-52.80) when compared to the upper three ($\bar{x}$=47.6, 95% CI 44.5-49.6). Furthermore, noise pollution has been associated with disturbed sleep and increased cortisol levels (Halperin, 2014; Spreng, 2000).

In 2016, there were 16,000 vacant properties in Baltimore, 7.9% of total in 2010 and 8% in 2016 (BNIA, 2016). Vacant properties, part of a larger index of neighborhood disorder, was negatively associated with cortisol levels (β=-0.022, $P<.05$) among African American children (Dulin-Keita, Casazza, Fernandez, Goran, & Gower, 2012).

Sexual violence

Almost 52.2 million women (43.6%) in the United States will experience sexual violence in their lifetime, with 43% (11 million) having the first occurrence before age 18 (Smith et al., 2015). Of those who experience sexual violence, 18.3% are by an intimate partner (Smith et al., 2015), and over thirty percent of women are survivors of physical violence by an intimate partner (Smith et al., 2015). In 2010, reported life-time prevalence of partner and non-partner rape among Black women (22%) was 3.2% higher than White women (18.8%) and 7.4% higher than Hispanic (14.6%) (Black et al., 2011). Reports of the experience of sexual abuse as a child by Black or African American women have been as high as 65% (Bryant-Davis, Ullman, Tsong, Tillman, & Smith, 2010). Child hood adversity, including sexual violence has been associated with lower cortisol levels at waking as children been hs been associated with blunted cortisol

Purpose

Since most studies on the impact of greenness on stress have used actual immersion (e.g., forest bathing) (Mao et al., 2012), or measured greenness as percentage of tree canopy (Nehme, Oluyomi, Calise, & Kohl, 2016), what is needed now is to better understanding the complex interactions of total greenness (NDVI), stress (cortisol awakening response) and physiological resilience within contextual factors of the social and built environment (experience of trauma) of the neighborhoods and lives of urban dwelling African American women.

Therefore, this study examines the effect of greenness on stress and resilience to stress among African American women, ages 18-44 in Baltimore, Maryland, framed within the Society-to Cells Resilience theory.

There are two specific aims of this Study:

Aim 1: Examine the relationship of neighborhood greenness (normalized difference in vegetation index) and physiological resilience (ratio of cortisol to DHEA) among urban-dwelling African American women who are at high of HIV after controlling for factors of resilience including society level (safety in environment, educational & career opportunities) and community level (built environment) including adult and childhood experiences of sexual violence, crime, income, education, perceived stress, traffic proximity, vacant housing.

The hypothesis for the first aim is that urban-dwelling African American women living in neighborhoods with higher levels of greenness will have a healthy ratio of DHEA (1:5-7) at waking.

Aim 2: Understand the resilient potential of urban dwelling African American women living with different levels of greenness.

Therefore, we proposed the following research question:

What is the impact of greenness on the resilient potential of African American women within the social and built environment?

Aim one is addressed in Chapter 3 (manuscript 2) while the question posed in Aim three is answered in Chapter 4 (manuscript 3).

Importance for Nursing Science and Practice

This study provided foundational data that can be used in the future for the development of targeted health interventions to increase the modifiable factors of community greenness and citizens' behavior that can take advantage of its benefits. Increased knowledge about the impact of greenness on the resilience of African American women to stress within the social environment helps us be able to advocate for policies that decrease inequalities in environmental interventions and gentrification. The study moves the fields of nursing and environmental health science beyond a focus on chemical toxicity of environments, to include psychological toxicity and potential immunological benefits from the ecosystem (Demas & Carlgon, 2014). Nursing is a global profession and science that is well positioned within communities and the health care system. The nursing profession addresses the biological and environmental factors that promote community and individual resilience, and this study fits within that paradigm. This study gives policy makers, health professionals and health systems a better understanding of greenness as an instrument for promoting the health of communities. It gives policy makers data to support increases in funding for creating (i.e., planting trees and installing green roofs and walls) and maintaining existing green urban spaces. This study expands the nursing and environmental sciences by increasing knowledge of the factors contributing to morbidity and mortality from violence of vulnerable populations, including African American women who are already among the most vulnerable to environmental injustices (Perry et al., 2013). These issues and implications will be further discussed in Chapter 5.

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Figure 1

Potential Mechanisms

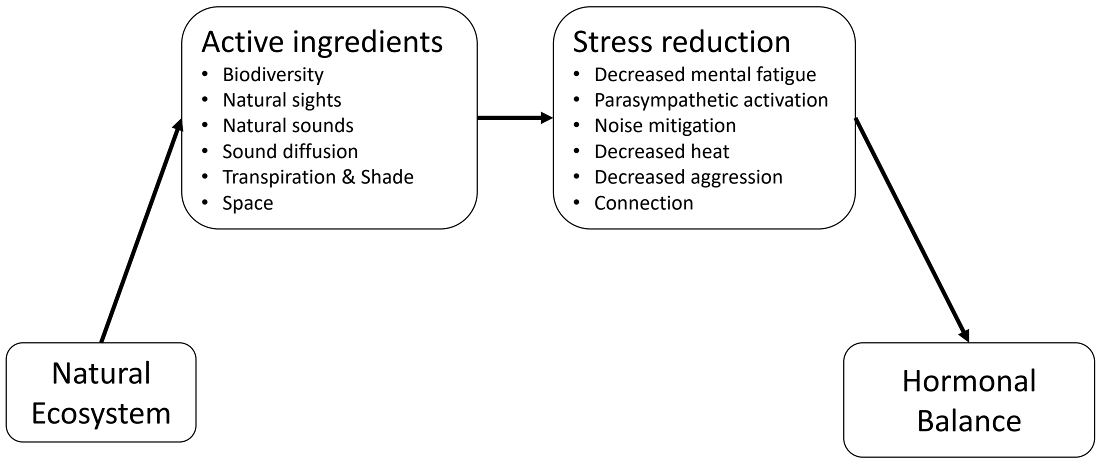
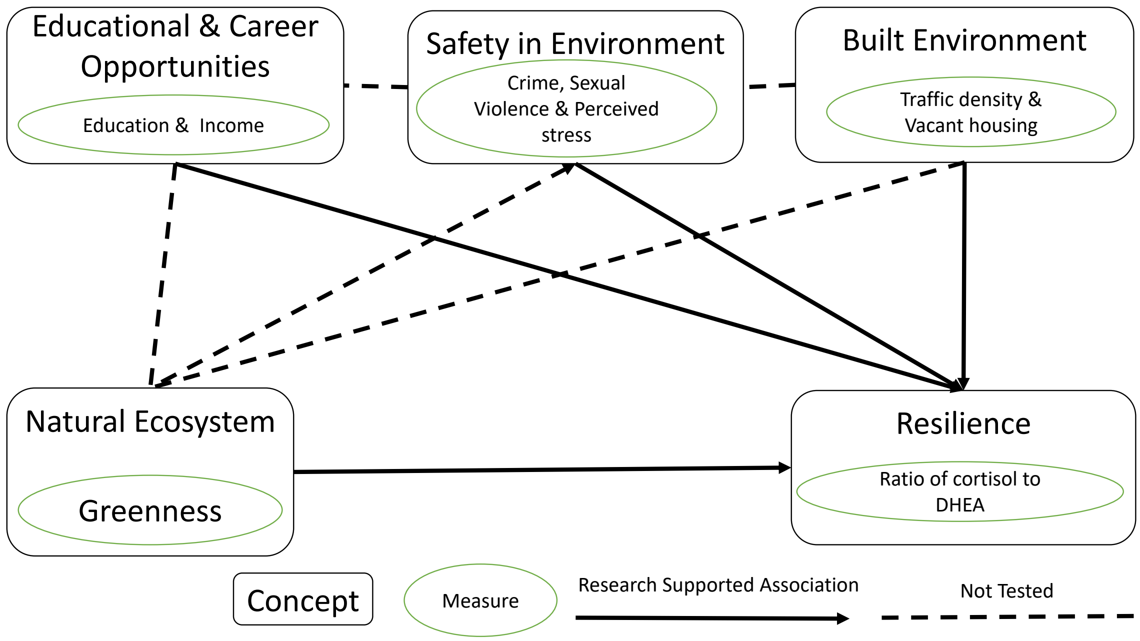


Figure 2

Conceptual Framework



CHAPTER TWO: MANUSCRIPT ONE

Integrative Review of the Intersection of Green Space and Neighborhood Violence

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Abstract

Purpose: To systematically analyze evidence about the impact of green-space on the perception and actual safety of residents of urban neighborhoods.

Design/Organizing Construct: Systematic review of green-space and violence based on Broome review criteria.

Methods: One landmark study prompted the initial hand search and identifying search terms. Twenty-three quantitative, five qualitative and two mixed method studies were discovered from urban-planning, public health, medical and psychological literature that met the following criteria: analyzed green-space and violence as factors in the perception of safety as an outcome measure, including action taken by being outside for recreation, exercise, or self-report in survey.

Findings: Findings were inconsistent regarding the direct relationship between perception of safety and green-space when using recreation and exercise as a proxy for perception of safety. Findings regarding perception of safety in surveys were limited but found a positive correlation with green-space. There is sufficient evidence to conclude that the perception of safety is supported by quality, accessibility and aesthetic dimensions of neighborhood green-space and the perception of safety is often unrelated to actual crime rates.

Conclusions: The science for understanding mechanisms between green-space and violence as part of environmental health has been insufficiently developed and requires further study. Environmental health, including green-space is central to health promotion and understanding is key to preventing the epidemic of violence.

Clinical relevance: This article provides a summary of research related to green-space, violence in communities, perception of safety, and violent crime in those communities. It identifies gaps in our knowledge where future research is needed. Nurses have the opportunity to lead the development, implementation, and evaluations of evidence-based interventions and policies addressing inequality of quality and quantity of green-space in the built and natural environment and related co-benefits.

Violence is a leading cause of death worldwide; an estimated 440,000 lives were lost due to violence in 2013 (WHO, 2016) In 2013, among those 15-34, homicide from assault was the third leading cause of death (11.5%) in United States of America (USA) (CDC, 2016). In Baltimore City, Maryland, USA, those ages 15-34 and Black or African American accounted for all 148 homicides in 2013 (CDC, 2016). In the same group, homicide accounted for 51.5% of mortality for males and 28% for females (CDC, 2016). For those who survive the assault, life-long health impacts can include disabling injury, chronic pain, other chronic health conditions, depression, and post-traumatic stress disorder (Campbell, 2002; McLaughlin et al., 2016). The health impact of morbidity and mortality from violence in communities and around the world have led to the prevention becoming a priority of the World Health Organization, the Centers for Disease Control, and city governments (CDC, 2009; City of Baltimore, 2014; WHO, 2015). Abnormally high temperatures are now a global phenomenon and have been associated with increased violence (Mares, 2013). Abnormally high temperature days have the greatest impact on those who are socially disadvantaged and who experience disadvantage by environmental health inequities, especially African American women (Mares, 2013). Intersecting challenges from changes to the climate, social disadvantage, environmental health inequity, and community violence demand that nurses and other health care providers, understand the mechanisms to facilitate primary, secondary, and tertiary prevention strategies and responses. Interdisciplinary research is needed to promote societal resilience (Szanton & Gill, 2010) to the intersecting challenges of environmental health and violence through evidenced based environmental, public and community health interventions.

Despite a landmark study by Kuo (2001) in a natural experiment comparing urban dwelling residents in the highest percentile of green-space to the lowest having the lower crime rates, lower reported violence in the home and higher community cohesion, there are few studies which further support this finding and little understanding of the mechanisms at work. Kuo, posited potential factors mitigating violence in the community to be the existing plants, including trees, flowers, grasses and bushes. The science thus far has not established if mitigation of violence and subsequent health improvements occurred due to increased presence of community members in common green-space areas, more opportunities for social interaction and social support with, "neighbors looking out for each other", increased opportunities for exercise in the neighborhood, stress reduction effects of aesthetic improvement or increased public display of care for homes. Is decreased aggression directly related to the presence of natural habitats in neighborhoods or is decreased violence due to some synergistic effect of all or some of these. To better understand the effects of green-space within neighborhoods, including the response of vulnerable populations to the presence or absence of green-space, this systematic integrative literature review (Broome, 2000) seeks to answer the following question;

"Within urban neighborhoods, what is the impact of green-space and violence on residents' safety and wellbeing?"

Methods

This is an emerging area of research and, therefore, the investigation began with an initial hand search of references citing the 2001 study by Kuo and Sullivan, and led to the following key words, "Environmental Restoration and Remediation" and "Urban Renewal" as mesh terms, "urban renewal", "environmental psychology", tree, trees, "green spaces", park or parks in the title or abstract. It included nature as a main heading, and “walking trail” or “walking trails" along with crime as mesh terms, including crime or violence in the title or abstract. The key words were used for an initial query in PubMed. Utilizing similar search terms in PschInfo, Embase and CINHAL added citations to those found in the hand search, initially capturing 1,607 articles (see Figure 3).

After limiting the search to the last ten years, English only, involving human subjects, peer reviewed and full text, the resulting collection included 498 articles. Removal of 232 duplicates left 266 articles to be reviewed by title and abstract for the first round of exclusion based on answering the research question. Inclusion criteria were studies that analyzed green-space and violence as factors in the perception of safety. Studies that operationalized the perception of safety by self-report in survey as well as those that used the proxy of action taken by being outside for recreation or exercise were included. Thirty-one articles were read completely, of which six quantitative articles were excluded due to having no measure of green-space included as a variable. This resulted in a total of 29 studies for review (see Figure 3). Many of the articles were interdisciplinary, for example medicine and urban planning, (Adams et al., 2011) and medicine and public health (Sugiyama et al., 2015). None of the included articles were published in nursing journals. The majority of researchers were from public health, urban planning, and exercise physiology. Study sites included one clinic (Roos, Myezwa, & van Aswegen, 2015), one at the neighborhood level (Adams et al., 2011), one at the provincial level (Côté-Lussier, Barnett, Kestens, Tu, & Séguin, 2015), with most in urban cities (n =25). One study looked across suburban, semi-suburban and urban areas

(Loptson, Muhajarine, Ridalls, & Smart Cities, Healthy Kids Research Team, 2012), although the majority of areas in that study were in urban areas (n=17). Two studies were national level studies (Jongeneel-Grimen, 2014, Lachowycz, 2014). The studies as a whole represented 8 countries, primarily Australia, Canada, United Kingdom (UK) and USA, but also Japan and South Africa. Study populations ranged in age from five years (Lovasi et al., 2013) up to eighty-five years old (Sugiyama et al., 2015), with the majority among middle aged adults and five studies among children.

Results

The process of data extraction for this review drew upon integrative and meta-synthesis methods to facilitate a deliberate and consistent approach to creating a whole picture from the breadth of qualitative and quantitative literature. First a major concept was identified through a concept analysis of *Ecopsychological Safety*, the perception of safety, in mind and behavior, from harm or danger of human beings in their environment (Mancus n.p). This concept analysis as well as existing literature, led to the formation of the question. An iterative process, going back and forth from the literature to the question, continued with reviewing Garvin and colleagues (2013) randomized, quasi-experimental study (n=21). The results of which suggested that the presence of green-space decreased the net incidence of crime (-4.0 difference-in-difference), and significantly increased perception of safety ($p<0.01$). One observational study (n=1,285) with a convenience sample of children (age $\bar{x}$=13.14, Female=53.9%) revealed increased green-space to be associated with decreased perception of neighborhood disorder (-0.18 SE 0.03 $p\leq.001$, n=1,285) (Côté-Lussier et al., 2015). These findings, while potentially beneficial to those responsible for public health and safety policy, become less straightforward when others are considered. For example, one matched case control study with an experimental randomization of sites suggested *non-significant* decreases in homicides, assaults, and robberies with guns within a half mile of fifty-two green storm-water infrastructure sites (β= -0.04 SE 0.05, β= -0.03 SE 0.04, β= -0.03 SE 0.02 respectively) (Kondo, Low, Henning, & Branas, 2015). Firm conclusions from these studies elude policy makers and suggest the need for more accurate measurement of greenspace and its impact on violence.

The use of Geographic Information Systems (GIS) quantified proximity to parks and green-space (Cerin et al., 2016; Cutts, Darby, Boone, & Brewis, 2009; Kondo et al., 2015; Ou et al., 2016; Ribeiro, Pires, Carvalho, & Pina, 2015; Ries et al., 2009), percentage of green-space (Roman & Chalfin, 2008), percentage of tree canopy (Kuo & Sullivan, 2001; Nehme, Oluyomi, Calise, & Kohl, 2016), Generalized Land Use Data (GLUD) (Lachowycz & Jones, 2014), areas of attractiveness (Tachikawa & Hashimoto, 2007), social and built environment (Deweese, Yedidia, Tulloch, & Ohri-Vachaspati, 2013; Garvin, Cannuscio, & Branas, 2013; Lovasi et al., 2013), and Normalized Difference Vegetation Index (vegetation) (Côté-Lussier et al., 2015) (see Table 1). Global Positioning Systems (GPS), a tool in GIS, have been used in combination with an accelerometer and found children's' moderate to vigorous physical activity in parks to be more than four times higher ($p<.001$) in parks than in their homes. However, parents' perceptions of neighborhood safety including signs of physical disorder influenced their decision making on children access (Cerin et al., 2016). The use of GPS and other satellites systems including Landsat imaging have increased the capacity to measure green-space, however, there still exists a gap in a consistent unit of measure.

Green-space has been positively associated with "walkability" of neighborhoods and with physical activity in large homogenous studies limited to female, white, middle aged, higher income and educated populations (Adams et al., 2011; Kurka et al.,2015, Sugiyama et al., 2015). Parents' perception of safety and allowing physical activity of children were significantly and inversely related to signs of physical and social disorder (n=73, β=2.17, SD=0.86) (Cerin et al., 2016), reported violence (n=254, p<0.0001) (Kalish et al., 2010) in two studies but these findings were not replicated. Among Asian and Asian-Pacific Islander Americans environmental physical activity supports including greenspace was the highest predictor of activity (OR = 1.52, CI = 1.06-2.17, n=263) (Bungum, Landers, Azzarelli, & Moonie, 2012). Thus far the use of instruments and measurement of green-space have been inconsistent in these studies and there have been only a peripheral focus on green-space (see Table 2) (Bungum et al., 2012; Esteban-Cornejo et al., 2016; Jongeneel-Grimen et al., 2014; Kalish et al., 2010; Leslie et al., 2010; Shinew et al., 2013).

A review of mixed method studies and examples of calculated green-space, as well as surveys and interviews with Latino Adolescents 12-19 years old (Female 53%) uncovered themes of (1) neighborhood disorder and safety (Shinew, Stodolska, Roman, & Yahner, 2013), and (2) nature and attractiveness (Tachikawa & Hashimoto, 2007) in qualitative analyses. Similar to findings in qualitative studies (see Table 3) in Canada (Loptson et al., 2012), UK (Seaman, Jones, & Ellaway, 2010), South Africa (Roos, Myezwa, & van Aswegen, 2015) and the USA (Rader et al., 2015; Stodolska, Shinew, Acevedo, & Izenstark, 2011) Themes revealed of green-space promoting sense of safety and pleasantness in neighborhoods (Loptson et al., 2012; Stodolska, et al., 2011;

Tachikawa & Hashimoto, 2007), perception of people as friends in greenspaces (Loptson et al., 2012; Roos et al., 2015), perceptions of quality, accessibility and positive aesthetics of green-space, as well as perception of social capital and neighborhood cohesion related to green-space (Loptson et al., 2012; Roos et al., 2015; Seaman et al., 2010). In contrast, when people perceived green-space users to be “others” (Rader et al., 2015; Shinew et al., 2013; Stodolska et al., 2011), perception of crime was higher (Rader et al., 2015; Seaman et al., 2010; Tachikawa & Hashimoto, 2007), perceived quality of green-space was lower (Roos et al., 2015; Shinew et al., 2013; Stodolska et al., 2011). In these cases, there is a report of increased fear, and decreased outdoor activity across age groups, ethnicities and nationalities (Rader et al., 2015; Roos et al., 2015; Seaman et al., 2010; Shinew et al., 2013; Stodolska et al., 2011; Tachikawa & Hashimoto, 2007). Overall there is an increase in the perception of safety in regard to neighborhood green-space, with other factors of the social and built environment contextualizing residents experience.

Perception of safety and actual safety based on crime statistics are well supported in several studies that evaluated the effect of green-space on urban violence, although perception and actual violence are not always correlated (Cerin et al., 2016; Kurka et al., 2015). Kalish et.al (2010) in an observational study found that approximately 60% of parents (n=254, Female 89%, 21-35year olds 76%) were concerned about safety of children (5-7 years old) playing in parks with poor conditions (2010). Another observational study (Cerin et al., 2016) reported that low crime and, to a greater degree, perception of neighborhood safety from crime resulted in increased moderate to vigorous physical activity (MVPA) (n=73) among children ($\bar{x}$=4.5yrs). An additional observational study (n=757) reported that children, whose parents perceived the neighborhood to be unsafe, experienced decreased MVPA by thirteen minutes per week (Kurka et al., 2015). The perception of the built environment, including green-space, frames the perception of neighborhood safety and impacts health related behavior.

The quality of and proximity to green-space are not equal in neighborhoods (Cutts et al., 2009; Ou et al., 2016; Ries et al., 2009), nor is there equity in actual amount of green-space available in neighborhoods (Lachowycz & Jones, 2014; Nehme et al., 2016; Roman & Chalfin, 2008). Quality, proximity, and amount of green-space within the neighborhood is significantly associated to the mechanism of green-space as a facilitator of safety (Kuo & Sullivan, 2001; Rader et al., 2015; Stodolska et al., 2011). The nearness of parks and with walkability has been found to be associated with physical activity, a proxy for the perception of safety (β=1.63, SE=0.16, p=<0.000, n=1046) (Cutts et al., 2009). An observational study of adolescents in a mid-Atlantic city (n=329, African American 69%, females 59%, mothers with college or higher education 40%) found park quality (Adjusted OR=2.29, SE=0.63) and availability (Adjusted OR=2.97, SE=1.23) were predictors of physical activity and park use (Ries et al., 2009).

Discussion

Quantitative findings of quality (Kalish et al., 2010) and pleasantness (Deweese et al., 2013) similar to the qualitative theme of quality, accessibility and aesthetics (Loptson et al., 2012; Roos et al., 2015; Seaman et al., 2010) lends support to the hypothesis that there is a positive impact of greenness on safety. While data collection has been more superficial in the measure of green-space as compared to other factors of perceived safety such as neighborhood disorder (Côté-Lussier et al., 2015; Garvin et al., 2013; Shinew et al., 2013) and community cohesion (Côté-Lussier et al., 2015), there is a sufficient foundation of knowledge to support the need for more research. The science of green-space and its relationship to violence needs further study in understanding how proximity, quality, amount, and accessibility to green-space are moderators of violence. Amount of green-space for these studies requires more accurate measures like the Normalized Difference Vegetation Index (NDVI). The use of NDVI is growing in global and public health. This validated ground level survey of vegetation uses satellite imagery and is calculated as near-infrared radiation minus visible radiation divided by near-infrared ration plus visible radiation (Rhew, Stoep, Kearney, Smith & Dubar, 2011). Preliminary evidence suggesting that quality green-space promotes safety requires further exploration. Research needs to investigate outstanding questions about proximity, quality, and quantity of green-space.

Limitations

The findings in this systematic literature has several limitations. One author was responsible for screening the articles and abstracts. In addition, the same author was responsible for the representative reduction of the data. Due to the language limitations of the author, English only studies were included, potentially missing other significant contributions. The inconsistent measure of green-space and perception of safety in this young science limits comparison. Furthermore, the gap of knowledge in nursing literature inhibits leadership and action.

Conclusion

The science of green-space and violence is in its infancy. Future studies need to explore psychosocial factors such as mental fatigue, immune function and stress response related to lack of green-space, as well as how individuals, families, communities, and different populations experience the intersection of green-space and violence. Evidenced based interventions guided by social and environmental justice that increase the quantity and quality of green-space in neighborhoods has the potential to prevent violence. It has the co-benefits of mitigating urban heat island effect, air pollution, noise pollution (Livesley, McPherson, & Calfapietra, 2016), the associated health outcomes including decreased mortality from cancer, respiratory illness, and kidney disease (James, Hart, Banay & Laden, 2016). Nurses need to be knowledgeable and engaged in advocacy of policies that promote healthy built and natural environments that mitigate violence and associated morbidity and mortality, as it is where the public work, play and sleep that is the foundation of individual, family and community health (ICN, 2011). Nurses and other health care providers collaborating through transdisciplinary action to promote planetary health, health from the local to the planetary level is the opportunity of our lifetime.

Clinical Resources

- Alliance of Nurses for Health Environments: http://envirn.org/
- Built Environment and Health Initiative: http://www.cdc.gov/healthyplaces/
- UNFAO, Urban Forestry Community: http://www.fao.org/forestry/urbanforestry/en/
- UK Forest Research: http://www.forestry.gov.uk/fr/INFD-9Q4FC8

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Table 1
Studies measuring green-space with geographic information systems (GIS)

Author, year, N	**Sampling/ Study Design**	**Setting/ Country**	**Sample Characteristics (Individual/Group)**	**GIS mapping/ greenspace**
Cerin et al., 2016, n=73,	Stratified/ Observational	Urban, United States	Parents; Age $\bar{x}$=32.6, US born 41%, Children; age $\bar{x}$=4.5, female 42%, Obese 31%	Activity in parks
Cote-Lussier et al., 2015 n=1,285	Convenience/ Observational	Provincial Level/ Canada	Children; age $\bar{x}$=13.14, Female 53.9%, Chronic poverty 13.26%	Greenery (NDVI)
Cutts et al., 2009, n=1046	Convenience/ Observational	Urban/ United States	High school or lower education; 48%, Poverty 16%,	Proximity to parks
Deweese et al., 2013, n=765	Randomised/ observational	Low income cities/ United States	Children; age 6-11 49%, female 50%, non-Hispanic black 52%, Hispanic 39%, Household income less than 200% FPL 82%,	Distance to school/ Pleasantness (trees)
Garvin et al., 2013, n=29	Randomised/ pre-post-test (safety) & GIS (Crime)	Urban/ United States	Intervention group (Male=50%, Age $\bar{x}$=38.7, Race Black=100%) Control (Male=81.8%, age $\bar{x}$=51.7, Race Black 100%)	Proximity to green-space
Kondo et al., 2015, n=52 sites	Randomised/ matched case (site) control	Urban/ United States	52 Completed construction sites/ 186 control eligible sites	Proximity to greenspace
Kuo & Sullivan, 2001, n=98	Randomised (Natural Experiment), Post-test only	Urban/ United States	Demographics of occupants of 98 Buildings; Female 65%, African American 97%, unemployed 93%	Public safety Record/ tree-canopy
Lachowycz et al., 2014, n=165,424	Randomized/ Observational	Nation/ United Kingdom	Female 605, working age 77.3%, Ethnically homogenous 2% Asian, 2% Black African, .8% mixed, .4% Chinese other, 35.3 from lowest socioeconomic class	Percentage of green-space
Lovasi et al., 2011, n=428	Convenience/ Observational	Urban/ United States	53% female, Age $\bar{x}$=4, 11% non- Hispanic Black, 36% Mexican, 23% Dominican, 8% Puerto Rican, 16% Mixed or other Hispanic nationalities, 6% other	Mapping built environment
Nehme et al., 2013, n=231	Convenience/ Observational	Planned urban community/ United States	new residents in a planned neighborhood; Female 4.8, ages 18-39 54.3%, non-white 11%, no college 6%	Tree canopy in network buffer (1.5km)
Ou et al., 2016, n=354	Convenience/ Observational	Small City/ United States	Not Latino 39%, Latino 61%, age 43% 18-44,	Proximity to parks
Ribeiro et al., 2015, n=523	Convenience/ Observational	Urban/ Portugal	Female 61% age $\bar{x}$=73.7, Male $\bar{x}$=72.7	Proximity to green-space
Ries et al., 2009, n=329	Convenience/ Observational	Urban/ United States	Female 59%, African American 69%, Mother a college graduate or higher 40%	Proximity to parks
Roman et al., 2008, n=803,	Stratified/ Observational	Urban/ United States	59% Female, 68% Black, age $\bar{x}$=44.85	Percentage of green-space
Tachikawa et al., 2007, n=63 n=285	Convenience/ Interview & GIS (attractiveness) MM	Urban/ Japan	Female n=60, age $\bar{x}$=43, full time homemakers 26%, use of bicycle or walking as transport 33.8%, lived whole life in residential area n=51	Areas of attractiveness

Table 2

Studies using survey or instruments to study green-space

Author, year, N	sampling/study Design	Setting/ Country	Sample characteristics (individual/group)	Instrument/ measure of green-space
Adams et al., 2011, n=2199	Systematic / Observational	32 neighborhoods stratified on built environment factors/ United States	Female 45.3, age $\bar{x}$=47.29, At least College degree 63.2%, non-white 18%	Neighborhood Environment Walkability Scale (**NEWS**)/ Aesthetics (presence of trees)
Esteban-Cornejo et al., 2016, n=928	Convenience/ Observational	Urban/ United States	Female 49.5%, age $\bar{x}$=14.10, Racial minority 34%, Mother with College education or higher 64%	**NEWS-Y**/ Physical activity in parks
Kurka et al., 2015, n=757	Convenience/ Observational	Urban/ United States	Female 81.4%, age $\bar{x}$=41.0, non-white 7.3%,	**NEWS**/ Aesthetics (presence of trees)
Sugiyama et al., 2015, n=2684	Cluster/ Observational	Urban, suburban and rural area of seven states and territories/ Australia	Female 56%, age $\bar{x}$=54.4, tertiary education 44%, Unemployed 20%, Income <AUS $41,599 (37%)	**NEWS/** Aesthetics (presence of trees)
Bungum et al., 2012, n=263	Randomized/ Observational	Urban /United States	Asian and Asian-Pacific Islander Americans, age $\bar{x}$=49.11, Female 65%, Chinese 20.5%, Japanese 20.5%, Filipino 14.8%, Korean 5.7%, Other AAPIA 39.5%	Environmental Physical Activity Supports/ Nearness to parks
Jongeneel-Grimen et al., 2014, n=31,783	Convenience/ Observational Study	National Data/ Netherlands	Respondents in 2009, Female 55.61%, age 18-59 =71.68%, unemployed 32.92%, low to med low income 51.54%, urban 92.14%	Social cohesion, absence of physical and social disorder/Satisfaction with green-space
Kalish et al., 2010, n=254	Convenience/ Observational	Urban/ United States	Female 89%, Hispanic 76%, 21-35 76%, children 5-7	NA/Quality of parks
Leslie et al., 2010, n=502	Cluster/ Observational	Urban/ United States	Female 74%, Age $\bar{x}$=47.7, tertiary education 40%, employed 63%	Features of the Neighborhood Environment Scale/ Scenery & proximity to parks
Shinew et al., 2013, n=386	Convenience/ Observational & Interviews MM	Urban/ United States	Female 53%, age (12-19, $\bar{x}$=14.53), Born in USA 80%	NA/Fear of Crime, Victimization (Experienced, Witnesses) Perceived Community incivilities, acculturation.

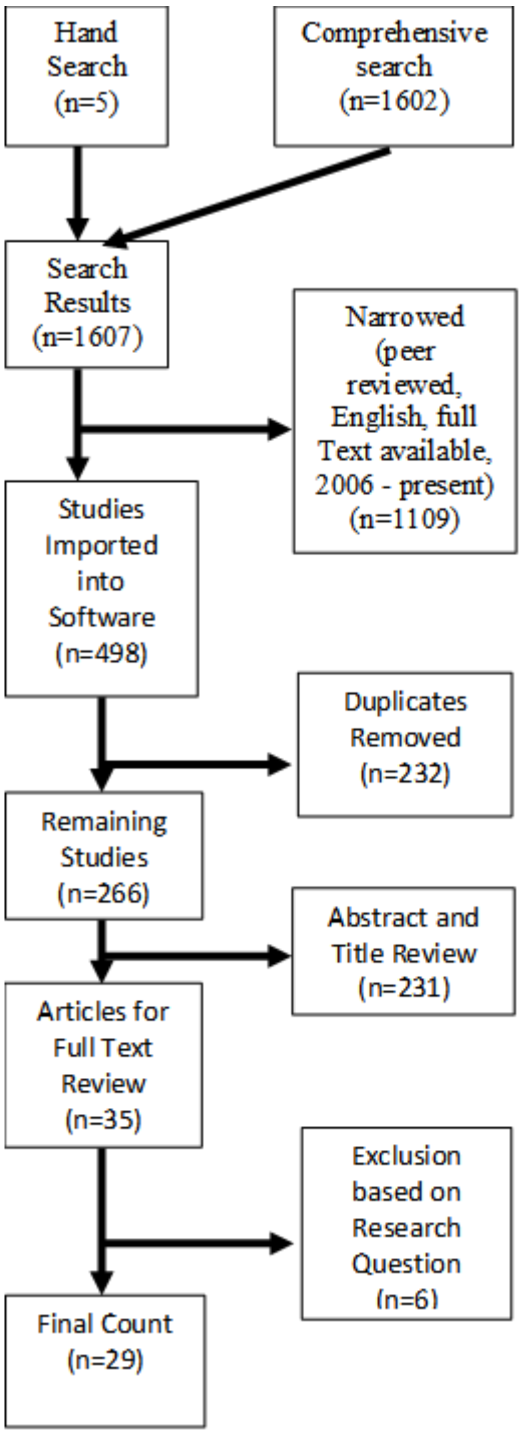
Table 3

Summary of qualitative themes

First author, year, N, Population, Country, Setting	Perceptions of safety/ Facilitators			Perceptions of fear/ Barriers		
	People as "Friends"	Quality, Accessible and Aesthetic	Social capital and cohesion	People as "Others"	Crime	Mismanaged or Inaccessible
Loptson et al., 2012, n=24, Parents of children 10-14 YO, Canada, Urban	X	X	X			
Rader et al., 2015, n=44, parents of school aged children, United States, Mississippi Delta				X	X	X
Seaman et al., 2015, n=24, adolescents and adults, United Kingdom, Urban	X	X	X	X	X	
Roos et al., 2015, n=42, PLWHA, South Africa, Clinic	X	X	X		X	X
Shinew et al., 2013. n=25, Latino Adolescents, United States, Urban				X	X	X
Stodolska et al., (2011), n=26, Mexican American Adults, United States, Urban		X	X	X	X	X
Tachikawa & Hashimoto, 2007, n=63, Adults, Japan, Urban	X	X			X	
YO= Year old PLWHA=People living with HIV and AIDS						

Figure 3

Details of Literature Review



CHAPTER THREE: MANUSCRIPT TWO

Relationship of green space and physiological resilience among urban dwelling African American women at high risk of HIV within the built and social environment.

Target Journal: Journal of Planetary Health

Abstract

Background

Vulnerable communities are burdened with social and built environments that foster aggression, including a lack of greenness, which has been associated with violence. As humans change the ecosystem that supports our health and civilization, those with the least amount of physiological resilience are at greatest risk of morbidity and mortality.

Methods

This cross-sectional study examined the association of greenness with physiological-resilience among Black and African American women (n = 98) between the ages of 18-44, living in a mid-Atlantic city. Salivary samples from waking were assayed for cortisol and dehydroepiandrosterone (DHEA) across two days.

Findings

We found a relationship where one standard deviation (0.039) increase in greenness was associated with a 34% increase ($\beta = 7.5$, $p<.05$) in physiological-resilience (operationalized as the ratio of cortisol to DHEA). We controlled for the factors impacting societal level resilience, including safety in the environment (crime, sexual violence, and perceive stress), educational and career opportunities (education and income), as well as the built environment of communities (traffic density and vacant properties).

Interpretation

The findings related to greenness and an increase in ratio of cortisol to DHEA must be interpreted with caution given the current state of science about cortisol and DHEA as well as the limitations in our data, especially the sampling strategy. Nonetheless these

findings are a foundation for continued investigation of the benefits of greenness to individual health.

Funding

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Introduction

In the United States, over thirty percent of women report physical violence by an intimate partner, including sexual assault by that partner (Smith, Singh, & Myers, 2015). In 2010, reported lifetime prevalence of partner and non-partner rape among Black women (22%) was 3.2% higher than White women (18.8%) and 7.4% higher than Hispanic women (14.6%) (Black et al., 2011). Reports of the experience of sexual abuse as a child by Black or African American women have been as high as 65% (Bryant-Davis, Ullman, Tsong, Tillman, & Smith, 2010), compared to the overall sexual abuse prevalence before age 18 of 43% in the United States (Smith et. al, 2015).

Additional stress for Black or African American women comes from social and built environmental inequality (structural racism, income inequality, crime exposure, noise pollution and neighborhood disorder) (Casey et al., 2017; Dulin-Keita, Casazza, Fernandez, Goran, & Gower, 2012; Friedson & Sharkey, 2015). Changes in the climate are predicted to increase violent crime by 3% (95% CI [1.5, 5.4]) by the end of the century, based on a median carbon dioxide emissions trajectory (Hsiang et al., 2017). Each of these sources of stress will be addressed below in each paragraph and linked to physiological indicators of altered stress response.

Biological Stress Response

The Hypothalamic-Pituitary-Adrenal (HPA) Axis, a neuroendocrine system that works in concert with the limbic system including the hippocampus, anticipate threats based on past experience prior to waking and begin to release a cascade of hormones ultimately causing the release of cortisol from the Adrenal Cortex as part of the cortisol awakening response, a rise in levels that peaks 1 hour after waking (Kamin & Kertes, 2017). The cortisol awakening response is part of the diurnal rhythm of cortisol as it fluctuates throughout the day peaking shortly after waking up and slowly declining throughout the day with the lowest point in the middle of the sleep period (Chan & Debono, 2010). Exposure to stressors increase the release of cortisol at the point of engagement with a stressor, peaking after the stressor has ended (Izawa et al., 2008). Prolonged exposed to stress and cortisol may alter the structure and function of the limbic system, including the hippocampus (Bartsch, 2012; Jin et al, 2016). Alterations in the hippocampus from chronic stress may contribute to lower levels of waking cortisol.

Cortisol on its own has been more extensively studied as a marker of response in the body to stress, especially to violence and mental well-being, including waking cortisol levels (Coulon, Wilson, Van Horn, Han, & Kresovich, 2016), cortisol rise (the rise in cortisol levels measured 30-minutes after waking)(Adam et al., 2015), and the diurnal slope of changes in cortisol throughout the day, measured from the peak (about 1 hour after waking) to the lowest point around (around midnight) (Ice, 2005). Among women both living in a domestic violence shelter (n=76) and those living with abusive partners (n=73), negative associations (β =-0.55, P<.001) between the chronicity of severe violence and the rise in cortisol levels from waking to 30 minutes later have been found (Pinto, Correia-Santos, Costa-Leite, Levendosky, & Jongenelen 2016). In other words, those with more chronicity of severe abuse had less rise in cortisol levels from waking to 30 minutes later. In a case control study, girls with major depressive disorder (n=63) had lower waking cortisol than a control group (n=68), but then rose higher than controls 30 minutes later (Ulrike, Reinhold, & Dirk 2013). A significant predictor (p<.05) for waking cortisol among a group of women (n=52, mean age=34.29, 48% African

American) was chronicity of abuse, as those with more chronic abuse had lower waking cortisol (M=11.11) than those with less chronic abuse (mean=12.57) (Johnson, Delahanty, & Pinna 2007). In that same group the women with less chronic abuse had a non-significant higher rise in levels of cortisol from waking measured 30 minutes later among those with less chronic abuse (rise in levels =3.65nmol/l) than those with more chronic abuse (rise in levels=3.04nmol/l). Waking cortisol and the rise of cortisol levels from waking measured 30 minutes later among African American young adults (n=50) with a higher perception of social discrimination was lower (waking level=5.13nmol/l, rise in levels=2.64nmol/l) than those with a lower perception (waking level =7.43nmol/l, rise in levels=2.95nmol/l) (Adam et al., 2015). In one study of 122 women (Mean Age=34, SD=6.22) those who experienced physical intimate partner violence had a shallower decline in levels of cortisol from 1 to 10 hours after waking than those unexposed (Kim et al, 2015). In summary, cortisol levels at waking are lower among those who have experienced chronic violence, depression, and discrimination. Cortisol levels measured 30 minutes after waking among young adults were lower among those with chronic violence and higher among young girls with depression.

Dehydroepiandrosterone (DHEA) and its sulfate DHEA-S collectively referred to as DHEA(S) are among the most abundant hormones in the body (Maninger, Wolkowitz, Reus, Epel, & Mellon, 2009). Circulating levels of DHEA (half-life 30 minutes), are lower than DHEA-S (half-life 10-20hrs) (Stárka, Duˇsková, & Hill, 2015). Levels of DHEA increase starting in adrenarche until the mid-20s and then start to decline across the rest of the lifespan (Karmin, & Ketes, 2017). DHEA levels are generally stable across the day, with a small increase in response to stress.

Among a group of male students (n=33) participating in a stress test showed levels of DHEA increasing faster than cortisol and before the stressor, then plateauing and dropping soon after the stressor, whereas cortisol kept increasing (Izawa et al, 2008). The fall in DHEA is in part due to antagonist action with cortisol, where DHEA binds to glucocorticoid receptors and the conversion into DHEA-S (Kamin & Kertes, 2017; Ghiciuc et al., 2011). The antagonist action of DHEA works in conjunction with cortisol's own negative feedback loop that signals the HPA Axis to stop production of cortisol (anti-glucocorticoid) and limits potential damage to the hippocampus (Bartsch, 2012; Gubba, Fawcett, & Herbert, 2004). In addition, neuroprotective mechanisms of DHEA are theorized to come from supporting cerebral stem cells (Karmin & Kertes, 2017). Therefore the ratio of cortisol to DHEA as part of the stress response is smaller up to the moment of the stressor, when the ratio gets larger as cortisol levels rise in response to stress. After the stressor is over and the body recovers the ratio falls back to the smaller pre-stressor ratio.

Evidence of Stressors for Black Women with Physiological Link

Income inequality disproportionately affects women, particularly African Americans (U.S. Census, 2016). The mean income of females (mean=$34,788) is 62% of the United States as a whole (mean= $55,322). For all Blacks or African Americans, the mean income (mean= $26,487) is 47% of the national average. In contrast, for Black or African American females, the mean is 45% ($25,234) of the national average, with 27% living below the federal poverty line in the preceding 12 months (U.S. Census, 2016). Although a slightly higher percentage of Black and African American women graduate high school (29%) and start college (26%) when compared to the U.S. averages (28% and

21% nationally), fewer receive a bachelor's degree (14%) and graduate/professional education (9%) when compared to the national averages (19% and 12%, respectively). The history of structural barriers in regards to race, class, and gender reinforce the cycle of poverty and (Najman et al., 2018). Female adolescents (n=418, age=11-15, Black=12%) living with household income to needs ratio less than 2 (poverty) during infancy (0-1 year) level had lower waking cortisol (β=-0.081, p<.01) than those not living with poverty a infants (McFarland & Hayward, 2014). In the same study adolescent girls currently living with poverty had were more likely to have lower levels of waking cortisol (β= -0.106, p<.01) than who those not living with poverty. In summary, Black and African American Females, have a lower income earning potential, setting them up for a lifetime of economic hardship and increased risk of lower waking cortisol levels.

Violent crime rates in the United States for 2016 (386.3/100,000 people) were almost half what they were in 1997 (611/100,000 people) (FBI, 2017). Reductions in crime were across social stratum. Yet in one observational study, five US cities (Chicago, Cleveland, Denver, Philadelphia and Seattle) had higher rates of average exposure to violent crime for the poor at the end of the decade (2007-2012), than non-poor at the beginning of the study (Friedson & Sharkey, 2015). While the greatest declines in exposure to crime were among Blacks and Hispanics, their exposure rates were higher than Whites for all the cities at the end of the decade (Friedson & Sharkey, 2015). Exposure to crime was also higher for Blacks and Hispanics at the end of the decade when compared to Whites at the beginning of the decade (Friedson & Sharkey, 2015). In terms of biological responses, violent crime within 500 meters has been associated in children with steeper declines in diurnal cortisol across the day until bedtime (β=-0.032, p<.05) and higher levels of cortisol after a stress test (β=.029, p<.01) (Theall, Shirtcliff, Dismukes, Wallace, & Drury, 2017).

In the United States, there are non-significant differences in mean ambient human caused noise pollution between the lowest income quartile block groups (M=47.6, 95% CI 47.3-52.80) when compared to the upper three (M=47.6, 95% CI 44.5-49.6) (Casey et al., 2017). Similarly, there was a non-significant difference between Whites (M=47.1, 95% CI 43.3-49.2) and Blacks (M=49.7, 95% CI 47.6-52.6) in ambient human caused noise pollution (Casey et al., 2017). Regardless, noise pollution has been associated with disturbed sleep and increased cortisol levels when asleep (Halperin, 2014; Spreng, 2000).

Vacant housing units in the US contribute to neighborhood disorder (Garvin, Branas, Keddem, Sellman, & Cannuscio, 2013; US Census 2016). Vacant properties, part of a larger index of neighborhood disorder, was a significant (P<.05) predictor of lower serum cortisol levels (β=-0.022) among African American children (n=148, mean age=8.28) (Dulin-Keita et al., 2012).

In summary, Black and African American women are inequitably burdened with environments that promote stress, the stress response and loss of the capability to recover. Over the life time the accumulation of stressors decreases the ability of the body to compensates resulting in lower waking cortisol levels.

Green Space and Stress

Amenities, including parks, green spaces, street trees and urban vegetation that provide a host of ecosystem services are also inequitably distributed: African Americans are twice (estimated prevalence ratio=2.31, (95% CI 2.09, 2.55) as likely to live on streets with no tree canopy and at least 50% impervious surfaces as non-Hispanic whites (Jesdale, Morello-Frosch, & Cushing, 2013). Measures of greenness, the collective natural environment in urban areas including, urban forests, parks, gardens, trees, brush and grasses has included percentage of tree canopy (Nehme et al., 2013), quantifying trees and grasses from images (Kuo & Sullivan, 2001), distance to parks (Deweese, Yedidia, Tulloch, & Ohri-Vachaspati, 2013) and from remote satellite through the calculation of normalized difference in vegetation index (NDVI) (Côté-Lussier et al., 2015), a validated tool (Rhew, Vander Stoep, Kearney, Smith, & Dunbar, 201l). Landsat satellites collect near infrared (NIR) and visible red (RED) light reflected off chlorophyll in plants, and through a calculation (NDVI=(NIR-RED)/(NIR+RED)) the average types of surfaces in 30 meter pixels can be estimated. Greenness (NDVI) measures the amount of healthy vegetation, which has been associated with mental (Chawla, Keena, Pevec, & Stanly, 2014) and physical health (James, Hart, Banay & Landen, 2016). Among women living in deprived urban communities at three hours post wakening, there were non-significant differences in cortisol levels with low green space ($\overline{M}$=4.24nmol/L, SD=2.03) than high (M=6.43nmol/L, SD=3.5) (Roe et al., 2013). Levels of greenness has been associated with decreased odds of having dehydroepiandrosterone (DHEA) in the lowest 10th percentile by 54% in laboratory collected salivary samples “mostly in the morning” (Egorov et al., 2017).

Lack of supportive ecosystems, concentrated disadvantage, and exposure to violence impacts resilience potential (Aiyer, Heinze, Miller, Stoddard, & Zimmerman, 2014; Chepesiuk, 2005; Garvin et al., 2013; Spreng, 2000; Ulmer, Harris, & Steffensmeier, 2012). Greenness is one way of measuring biological diverse spaces supportive of individual and community recovery from past stress, resistance current stress, and rebounding to higher levels of capability (Irvine, Warber, Devine-Wright & Gaston, 2013; Szanton & Gill, 2010). In summary, those living in social and built environments that promote stress are at increased risk of low waking cortisol and DHEA levels but greenness may decrease that risk.

Ratio of Cortisol to DHEA

The ratio of Cortisol to DHEA has been suggested as a potential biomarker of physiological resilience (Petros, Opacka-Juffry, & Huber, 2013; Walker, Pfingst, Carnevali, Sgoifo, & Nalivaiko, 2017; Yehuda, Brand, Golier, & Yang, 2006). Cortisol and DHEA both support the body in responding to stress. Cortisol facilitates the release of glucose to react to potential threats and mitigate inflammation. The ratio of cortisol to DHEA with its neuroprotective and anti-glucocorticoid activities is an important marker of the body's response to stress. The ratio of cortisol and DHEA in salivary samples has been studied as part of a number of stress tests (Jiang et al., 2017; Lam, Sheilds, Traineor, Slavich, & Yonelinas, 2018; Prall, Larson & Muehlenbein, 2017). Jiang and colleagues found non-significant (p=.216) differences in the ratio of cortisol to DHEA among college students (n=81, 18-26 years old) with depression disorder (mean ratio=4.94 [4.1, 5.7]) compared to a control group (mean ratio=5.2 [3.9, 6.3]) (2017) at baseline. In the same study 50 minutes after a stress test the ratio of cortisol to DHEA increased by 112% (range 86%-256%) among the normal control group and the by 106% (range 92-249%) in the depressive group (Jiang et al., 2017). Lam and colleagues found pre-stress baseline cortisol (4.99 nmol/l) and DHEA (.77 nmol/l) levels in a ratio of 6.48:1 among a group of "healthy young adults" (n=61, mean age=20.62, F=59%) (2018). In that same study the post stress ratio of cortisol (mean=11.77, SD=11.04) to DHEA (mean=1.04, SD=.98) was 11.32:1 (Lam et al., 2018). Prall and colleagues found among a male only cohort (n=27) that the pre-stress ratio of cortisol (4.69 nmol/L) to DHEA (mean=0.47 nmol/L, SD=.32) was 10:1, while the post-stress ratio of cortisol (mean=7.17 nmol/L, SD=3.86) to DHEA (mean=.58 nmol/L, SD=.3) was 13:1 (2017). In comparison, Jin and colleagues found non-significant baseline, non-stress test associated blood serum cortisol to DHEA ratios of 1.35:1 (SD=0.426) among young adults with major depression disorder (n=18, mean age=37.3, Female=50%) and 1.30:1 (SD=0.913) in the controls (n=19, mean age=35.5, Female=58%) (2016). Only one study to our knowledge has looked at the waking ratio of cortisol to DHEA, in a sample of healthy college-aged males (n=20) and females (n=18) sampled from a Midwestern university in a midsized "college town" (Prall & Muehlenbein, 2015). The women in the Prall and Muehlenbein study were found to have waking cortisol (mean=12, SD=4.9) and DHEA (mean= 0.36, SD=.297) at a ratio of 33.5:1 in this presumably low stressed sample (Prall & Muehlenbein, 2015). The single small sample study examining the ratio of cortisol to DHEA at waking, and the small sample sizes amongst all the other studies reviewed limit drawing firm conclusions as differences in the ratios are vulnerable to outliers that can skew the means resulting in values far from the median. In summary, the ratio of cortisol to DHEA is lower at baseline than post-stress test, among college-aged adults in salivary samples. The ratio of cortisol to DHEA in salivary samples at baseline ranged from 4.69:1 to 6:48:1 and post stress test from 4.94:1 to 33:1, considering waking to be a post-stress period.

Waking elevation of cortisol and DHEA are to be expected as part of the cortisol awakening response, with cortisol at higher ratio levels than DHEA in healthy populations at wakening (Karmin & Kerters, 2017). A low ratio at waking would indicated a low cortisol waking response, evidence of a blunted response, or that DHEA is elevated (Izawa et al., 2008). Elevated DHEA and low cortisol would suppress the release of glucose and anti-inflammatory activity as part of the waking stress response (Karmin & Kertes, 2017).

The ratio of cortisol to DHEA fluctuates throughout the day and throughout the lifetime (Karmin & Kertes, 2017). Among young and middle-aged adults at waking we would expect a higher ratio of cortisol to DHEA. A low ratio of cortisol to DHEA at waking due to low cortisol levels would the limit formation of glucose and capacity to protect cells, tissues and organs from inflammation indicating low physiological-resilience (Karmin & Kertes, 2017). Alternatively, a low ratio of cortisol to DHEA due to elevated DHEA accompanied by typical cortisol levels would also indicate low physiological-resilience for similar the same reasons (Karmin & Kertes, 2017). While DHEA is neuroprotective and important to the stress response, the dearth of literature about the ratio of cortisol to DHEA at waking and in general prevents the assumption that elevated levels of DHEA with low levels of cortisol are without risk (Karmin & Kertes, 2017).

Both analysis of the diurnal cortisol slope and the ratio of cortisol to DHEA are representative of emerging trends in research on the physiological stress response. Drawbacks in sampling in non-laboratory settings relate to potential interactions from external stressors that participants would experience throughout the day and participant burden. Diurnal cortisol slope could be impacted by stressful interactions inflating general trends depending on how many samples were taken over the day (Hoyt, Ehlrich, Cham, & Adam, 2016). More samples throughout the day would increase the burden placed on participants in collecting and storing samples if they were to go to work or leave the house (Hoyt, Ehlrich, Cham, & Adam, 2016). The advantage of waking ratio of cortisol to DHEA it has a much lower burden on participants and the sleep period before quiets “noise” in the data from episodic events (Karmin & Kertes, 2017).

In conclusion, the collaborative work of cortisol and DHEA collectively speak to the multi-dimensional capability of biological processes shielding cells, tissues, and organs from stress and the support healthy functioning (Karmin & Kertes, 2017; Szanton & Gill, 2010). Physiological-resilience is part of the theoretical framework of this study (Szanton & Gill, 2010). Physiological-resilience can be conceptualized as the capability to recover from conscious, unconscious, and cellular memories of stress, while at the same time enduring current stress, and transforming into a stronger more flexible state. Thus, physiological resilience involves a dynamic variation in hormone levels throughout the day and the lifespan (Karmin & Kertes, 2017). Although there has only been one study that has measured the waking ratio of cortisol to DHEA, and none thus far among African American women with multiple stressors as ours, the review above justifies operationalizing physiological resilience as the ratio of cortisol to DHEA with a higher ratio signifying more resilience. Cortisol and DHEA were the biological stress makers available to us from the parent study (see below). Therefore, the purpose of this study was to evaluate the relationships between greenness and physiological resilience, operationalized as the ratio of cortisol to DHEA among African American women, with and without past exposure to sexual and other forms of violence, as well as living in a mid-Atlantic city (Baltimore, MD) with built and social environmental inequality.

Method

Study design and participants

This cross-sectional study uses data from a multi-year study of the impact of environmental and sexual assault on women's physiological factors and HIV risk, called the ESSENCE study (NIHG R01HD077891, J. Stockman PI). The ESSENCE study recruited participants at two Baltimore City Health Department (BCHD) sexually transmitted infection clinics that serve low-income and uninsured individuals in the western and eastern parts of Baltimore, Maryland. Female clients of BCHD were approached in a systematic manner presenting a recruitment flyer and describing the study to potential participants. Eligibility included self-identifying as being biologically female, Black or African American, being between the ages of 18 and 44 years (mean = 26.67, SD=6.64), living in Baltimore City, Maryland, and having access to a freezer. Eligibility further required having been in sexual relationship with a man in the past six months and reporting one or more of eight HIV factors (see Table 4 for list and % of women experiencing that risk factor). All of the women had at least 1 unprotected sex partner and the largest percentage (50%) had 2 or more unprotected sex partners in the past year with at least one partner having 2 or more high risk behaviors. Similar to African American women in Baltimore City, the sample was fairly well educated with 33% having finished high school or got their equivalency (compared to 36% in Baltimore city), 10% having started college or vocational school, 12% who were college graduates and 9% completed graduate school. However, 60% of participants had an income of less than $10,000 annually. The median income for Black and African American women in Baltimore is $27,020 (US Census, 2016).

Saliva protocol

In addition to a survey, eligible participants were asked to collect saliva over three days at waking and thirty minutes later. Participants were given supplies and instructions when recruited, as well as in home demonstrations by ESSENCE team members, on the saliva collection protocol. Participants were asked to stay in bed and not to eat, drink, smoke or brush their teeth prior to and until finished with the daily collection of samples (Kuhlman et al., 2017). The passive collection of saliva was through a straw adapted collection tube to provide the most abundant and uncontaminated samples (Izawa et al., 2008, Granger et al., 2017). Self-collection support for participants included providing a phone and texts with reminders the night before and prompts at waking, and 30 minutes later based on participant suggested times, as the process can be challenging (Granger et al., 2007). Participants were instructed to place samples immediately into a freezer until picked up by ESSENCE team members (Pinto et al, 2016). Samples were then stored at -80 Celsius until being transported to University of California, Irvine for analysis (Granger, et al., 2007).

Measures

Individual level demographic data were collected from survey of participants (age, income, address and education). Addresses were imported as a comma separated file (CSV), and geographically coded in ArcGiS 10.4.1 (ESRI, 2015), a geospatial information system (GIS) that allows the user to build a base layer of point pattern data. From Sheridan Library (Johns Hopkins University, 2000), we obtained an ArcGIS shape file (data imbedded maps) with names, streets, addresses and zip codes of the city of

Baltimore, Maryland. This geocoded street map allowed for identification of the spatial X Y coordinates of participants' address on the map. Utilizing these X Y coordinates, other layers of data were joined together to create the final population level data file. Population level data were collected from publicly available data sets from the United States Geographical Society (USGS, 2016), the City of Baltimore, Baltimore Neighborhood Indicators Alliance (BNIA, 2016), and the United States Environmental Protection Agency (EPA, 2014).

Cortisol, DHEA and Ratio

Biological markers of cortisol and DHEA were assayed using 96-well microtiter plates with precision multichannel pipettes, an optical density reader, and technically trained lab personnel at the University of California, Irvine. All assays were duplicated. The two-day average of the duplicates was used in the analyses. Cortisol and DHEA were measured using Enzyme-Linked Immunoassay (ELISA) (Theall et al., 2017). The biomarkers were averaged across the two days of cortisol (mean=0.48, [2.1,7.4]) and DHEA (mean=414.0, [366.1, 461.9]. The means of cortisol (0.48ug/dl * 27.59=13.2nmol/l) and DHEA (414pg/ml *0.0028=1.2nmol/l) were transformed into a singular unit of measure to facilitate comparisons with the literature and for calculating the ratio (Petros et al., 2013). Then we divided cortisol by DHEA to create a value representing the ratio of the two values (mean ratio=11.9, SD=22.4) (see Table 5). Post-hoc analysis included calculation of the rise in cortisol from waking (mean=13.3, SD=36.4) to thirty minutes later (mean=10.5, SD=5.1), and the difference in the two as a measure of the rise (mean=2.45, SD=4.4).

Greenness

The United States Geographical Survey (USGS) stores data collected by the National Atmospheric and Space Administration (NASA) Landsat Satellites (USGS, 2018). Landsat 8, the eighth of a series of satellites, began operation in 2013. Landsat 8 captures images around the world every 16 days. Through the use of USGS website Earth Explorer, a Landsat scene captured on July 16th, 2016, including Baltimore City in daytime view, with high vegetation potential, and low cloud cover was obtained. The data from Landsat 8 includes spectral indices that include visible red (bandwidth 4) and near infrared (bandwidth 5). Utilizing the X Y coordinates from the participant point pattern data (personal identification number), a 100-meter circular polygon (buffer about the size of a typical city block in Baltimore) was created. These participant buffers were given the average of the NDVI scores that were within that 100-meter buffer.

Covariates

Covariates included cumulative experience of sexual violence, unprotected sex, income, education, crime, traffic proximity, and vacant property. Cumulative experience of sexual violence was a categorical variable representing those unexposed to sexual violence (n=57, 58%), those exposed as adults only (n=9, 9%), and those both as adults and children (n=32, 33%). Income was a binary variable representing those making above (33%) and below (77%) 200% of the Federal Poverty Level.

Crime data was collected from the City of Baltimore as point pattern data in a CSV file (City of Baltimore, 2018a). This file included the Global Positioning System (GPS) latitude and longitude point pattern data of each crime, as well as identification of the type (i.e., aggravated assault, rape and homicide). These latitude and longitude data were geocoded into individual crime type, point pattern data shape files and added to the layer with the existing participant data.

Additionally, from the City of Baltimore, longitude and latitude of vacant properties in 2016 was downloaded in a CSV file (City of Baltimore, 2018b), geocoded, and added to the participant point pattern data. Data on traffic proximity were gathered from the Environmental Justice Screen at the U.S. EPA and downloaded as polygon shape file at the statistical block group for Baltimore City (n=653) (US EPA, 2014). The traffic proximity and population data were added to the existing participant point pattern data. The Baltimore Neighborhood Indicators Alliance was the source of community statistical area (n=55) data used for cluster analysis. The Baltimore City community statistical areas (n=55) are in size between census tracks (n=200) and zip codes (n=21) and guided by neighborhoods (n=271) that allow for the census data to be contextualized by spaces that people know (Thorton, 2014).

Statistical analysis

The point pattern data of the participants was saved as a geographic map file, including a data-based file (.dbf) that was imported to SPSS (IBM Corp, 2017). In SPSS the data-based file variables were merged with data from the ESSENCE study, including survey (income, education, age, sexual violence, and childhood sexual abuse) and salivary biomarkers (DHEA and Cortisol). We analyzed data with univariate analysis by looking at the means, medians, standard deviations, skewness, kurtosis, histograms, frequencies, and stem and leaf plots of the variables. After initial exploratory analysis including bivariate associations, multivariate regression analysis and confirmatory factor analysis of psychometric measures, we built a multilevel generalized linear regression analysis of greenness and physiological resilience incorporating community and societal factors. Societal level factors included age, income, education, sexual violence, perceived stress and crime. Community level factors included vacant properties and traffic proximity. We analyzed data for clustering at the community statistical area level (n=55) and tested for collinearity. The model was built in Stata IC 14.2 (Stata Corp, 2015).

Results

In terms of demographics this highly stressed group included an exposed group (experienced sexual violence) who was 5.5 years older ($p<.01$, 95% CI 3, 8) than the unexposed group (did not experience sexual violence) (see Table 6). There were significant differences between the exposed and unexposed, including income less than $30,000 (200% of the Federal Poverty Level) (88% vs 68%, $p<.05$). Those who reported sexual violence had significantly more unprotected sex with partners (3.98 vs 2.45, $p<.05$) and higher perceived stress (.36 vs, -0.33, $p<.01$).

Greenness

Community Statistical Areas in Baltimore had average greenness measured as NDVI that range from 0.041to 0.217 (See Figure 4) when excluding the Patapsco river, as NDVI range for water is approximately -1 to -0.1. There was a significant negative association of greenness at 100-meters with crime by population at block group (β=-0.246, $p<.01$) (see Figure 5). In other words, the greener the space is at 100-meters from the participant's address, the less crime occurs. Greenness had a negative association with population adjusted traffic proximity (β=-0.011, $p<.01$). Vacant properties adjusted for population were also negatively associated with greenness (β=-0.19, $p<.01$). Age had a small but significant negative association with greenness (β=-0.001, $p<.05$) (see Figure

6). Perceived stress, income, and education were not significantly associated with greenness at 100-meters.

Biomarkers

We analyzed biological markers of the stress response (cortisol and DHEA) and their ratio for the 98 women in the sample (see Table 7). Due to the non-normal distribution, including positive skewness of the biomarkers and the ratio of cortisol to DHEA, we analyzed nine different transformations (see Figure 7), with the ultimate decisions to use logarithmic transformation and gamma distribution in the generalized linear model (Manning & Mullahy, 2001). When analyzing greenness without covariates, we found non-significant positive associations with log transformed cortisol (β=9.3, p=.097) (see Figure 8), DHEA (β=.71, p=.61) (see Figure 9) and the ratio of cortisol/DHEA (β= 4.7, SE=4.1 p=.255, 95% CI [-3.4, 12.8]) (see Figure 10).

Greenness was non-significant (β =7.5, SE=4.9, p=.124, 95% CI [-2, 17]) in the full adjusted model; however, when we clustered with community statistical areas (CSA) (n=55), we found one standard deviation (0.039) increase in greenness associated with a 34 % increase (β= 7.5, SE=3.39 p=.026, 95% CI [.89, 14.2]) in physiological-resilience (operationalized as the ratio of cortisol to DHEA). In other words, increased greenness was associated with increased physiological-resilience adjusting for the community and societal level factors. The final variance inflation factor to test for collinearity was acceptable (mean=2.11) (Belsley, Kuh, & Welsch, 2005).

Post-hoc analysis found a positive association of greenness with the rise of cortisol (β =16.7) at a significance level of p=.068 (see Figure 11) clustered at the CSA. Further post-hoc analysis of scatterplots with greenness with log transformed ratio of cortisol to DHEA for two community statistical areas in Baltimore, Penn North-Reservoir Hill, and Madison-East End, were visually suggestive of differences in those exposed in levels of greenness (see Figure12).

Discussion

The results of this study show that the associations between greenness and physiological resilience operationalized as the ratio of cortisol to DHEA are influenced by the built and social environment. While we found non-significant findings in cortisol and the ratio of cortisol to DHEA among those exposed and unexposed to sexual violence as adults, it was the inclusion of a categorical variable of exposure to sexual violence, including adult plus childhood as a covariate that resulted in statistical significance of the fully adjusted model.

The non-significant but positive association between the greenness of where people lived with cortisol (β = 9.3, p=.097), DHEA (β = .71, p<.61) and the ratio of cortisol to DHEA (β = 4.7, p<.33) were in the direction and strength expected. This sample of women was highly stressed related to their low income, lack of employment, living in neighborhoods characterized by crime and vacant houses, and relationship characteristics putting them a risk for HIV whether or not they had also experienced sexual abuse. As a group they had average waking cortisol (mean=13.2, SD36.4) higher than at 30 minutes (mean=10.5, SD=5.1) similar to other stressed groups (see Figure 13) (Barksdale, Woods-Giscombe, & Logan, 2011; Pinto, Correia-Santos, Cost-Leite, Levendosky & Jongenlen, 2016). The ratio of cortisol to DHEA in this study sample at waking (12:1) is lower than the ratio (33:1) among the only other study of women (n=18, strict inclusion and exclusion criteria) (Prall & Muehlenbein, 2015). Prall & Muehlenbein do not describe their sample of women recruited other than that they were recruited at a Midwestern university lab (2015). Slightly higher levels of cortisol and significantly higher DHEA levels in this study (cortisol=13.6nmol/L, [5.8, 20.5], DHEA=1.15 (95%CI [1.03, 1.29) compared to those in Prall and Muehlenbeing study (cortisol=12nmol/L SD=4.94,, DHEA=0.35,SD=0.25) (Prall et al., 2015), suggests anticipation of stress and compensatory action (Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2012). The elevated levels of cortisol and DHEA and the ratio are part of the complex system working to maintain optimal capability to respond to physiologically anticipated waking stress (Izawa et al., 2009). The non-significant positive association between greenness and the ratio of cortisol to DHEA even among those who reported sexual violence (see Figure 14) reflect the stress phase of the response (Prall et al., 2015), where DHEA peaks first as cortisol is still rising (Izawa et al., 2009).

The inclusion of population-adjusted traffic proximity ($\beta = 0.002$, p=0.987) and vacant properties ($\beta = -0.21$, p=98) in the model were negligible in the direct effect; however, the covariates help explain some of the random error in the relationships between greenness and resilience. While roadways without any tree canopy would have a low NDVI score, a roadway with high traffic and high canopy would give credence to the error explained by traffic proximity and noise pollutions impact on the stress response (Watts, 2017). Given constraints of space in cities, green spaces are subject to become roadways, and poorer neighborhoods more likely the site of roadways (Sugrue, 2014). The contribution of population adjusted vacant property to the model supports the literature in that the quality of the environment, including neighborhood disorder and socioeconomic factors affects the perception of green spaces and safety, and potentially the opportunity to access green spaces for potential benefits (Mancus & Campbell, 2018). Alternative explanations are that traffic proximity, vacant properties, income, education and greenness itself are all potential indicators of the ability of communities to leverage influence over their environment (Pretty & Ward, 2001).

Limitations and Strengths

This non-probabilistic sample included self-identified Black or African American women between the ages of 18-44 recruited at a sexually transmitted infection clinic in mid-Atlantic city. Not only are the results not generalizable but the nature of the sampling introduces selection bias since all of the sample are more likely to have experienced sexual abuse and other traumatic events than women living in other communities. In addition, the clinics are free to the citizens of Baltimore and are located in poor neighborhoods that are almost entirely African American due to the historical patterns of segregation and lack of investment.

The measure of greenness is an average measure within a 30-meter pixel measured from space. The 100-meter buffer used for this study is subject to influence from vapor in the air, pools, ponds, lakes, and rivers. While we excluded the largest body of water, the Patapsco River, we included other bodies of water, potentially underestimating the level of greenness of some participants. Furthermore, there is also no way to control for actual exposure to potential benefits of greenness if participants did not spend significant time outside. We were also unable to control for time at the address reported or if the address was invalid. There is also an issue of temporality as the NDVI was calculated with data from July 15, 2016, and we collected salivary samples over the years 2015 through 2018. The same questions of temporality exist in regard to crime (2016), vacant property (2016) and traffic proximity (2014).

Self-sample of salivary samples introduces a threat to test validity depending on the consistency of salivary samples being taken exactly at waking and at 30 minutes later. Furthermore, due to DHEA and cortisol samples coming from one time with the 24-hour diurnal variation, we are limited in our ability to predicted changes in both variables. Importantly, the use of the ratio of cortisol to DHEA to represent physiological resilience in the contemporary state of the science about the complex physiological response to multiple stressors over time and their biomarkers is hypothetical.

Another major limitation was the selection of factors controlled for in the multilevel modeling analysis. There is the issue of over controlling in analysis as well as not being able to see and understand the effect of any of the factors controlled for in the outcome. The exploratory analyses of the regression model with the given sample size and predictors likely resulted estimation of empty cells. Different analysis could have included creation of a binary outcome of the ratio of cortisol to DHEA and run as a logistic regression.

In spite of the limitations, to our knowledge this study is the first to examine at the association of greenness using remote sensing with physiological-resilience operationalized as the ratio of cortisol to DHEA among African American women at high risk of HIV at waking. The study gave us a unique opportunity to explore physiological-resilience and greenness, with the reference data of a unique and vulnerable population. We have also found a potential effect size (.34) for future studies in estimating power calculations examining the relationship of greenness and resilience. We recommend collection of longitudinal DHEA and DHEA-S samples for any future studies.

Conclusion

There are a great number of challenges facing human health and our civilization. Trees, plants, and other vegetation provide ecosystem services, including mitigation of the urban heat island effect and sequestration of carbon dioxide. The potential co-benefits of urban greenness as part of urban environments to protect against interpersonal violence and promote resilient physiology have implications for governments, health systems, and individual providers. Future research should consider seasonal changes in greenness, diurnal variation of cortisol, DHEA, DHEA-S, and the cumulative impact of violence.

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Table 4

HIV Risk Factors

	Partner risk behavior					
Unprotected sex partners	**0**	**1**	**2**	**3**	**4 or more**	**Total**
0	0	0	0	0	0	0
1	0	0	10	2	4	16
2	8	8	16	4	7	43
3	2	2	5	2	8	19
4 or more	1	3	2	5	9	20
Total	11	13	33	13	28	98

Table 5

Univariate Analysis of Cortisol to DHEA ratio

n=98	Mean [95%CI]	Median	Range [IQR]	Skewness	Kurtosis
Cortisol/DHEA	11.9 [7.38, 16.37]	6.97	1.9-190[4.47-10.43]	6.4	47.6

Table 6
Demographic data

(*=p<.05)	**Exposed (n=41) Mean [95%CI]**	**Unexposed (n=57) Mean [95%CI]**	**Total Sample (n=98) Mean [95%CI]**
Cortisol nmol/L	12.47 [3.03, 21.92]	13.66 [2.88, 24.44]	13.16 [5.8, 20.45]
DHEA nmol/L	1.10 [.89, 1.33]	1.19 [1.02-1.36]	1.5 [1.03, 1.29]
Cortisol/DHEA	12.2 [6.2, 18.2]	11.6 [6.2, 18.2]	11.9 [7.3, 16.4]
Greenness	.109 [.097, .120]	.118 [.108, .129]	.114 [.107, .123]
Age*	29.9 [27.7, 32.1]	24.4 [22.9, 25.8]	26.67 [25.34, 28.01]
Childhood Sex Abuse	n=32 (78%)	n=0	n=32 (32%)
Unprotected Sex part*	3.9 [2.31, 5.63]	2.45 [2.1, 2.8]	3.09 [2.37, 3.18]
Stress (n=84) *	0.35 [.049, .66]	-0.033 [-0.62, -0.034]	-.051 [-2.04, 1.86]
Education: High School or Less	n=30 (73%)	N=37 (65%)	n=67 (68%)
Income <$29,999*	n=36 (88%)	n=39 (68%)	n=75 (77%)
Traffic proximity by block group population	1.08 [.709, 1.46]	1.13 [.85, 1.42]	1.11 [.89, 1.33]
Crime by block group population	.0233 (.018, .028)	.0197 [.0149, .0244]	.0211 [.0177, .0246]
Vacant property by block group population	.015 [.0081, .0224]	.0109 [.0048, .0168]	.0127 [.0081, .0173]

Table 7
Full Model

Physiological-Resilience		Unadjusted		Model 9	
		Coef	pvalue	Coef	pvalue
Greenness		4.72	0.26	7.55	0.03*
Sexual Violence	Adult	-0.11	0.88	-0.27	0.27
	Adult & Child	0.09	0.83	0.38	0.29
Unprotected sex		0.02	0.69	0.04	0.08
Perceived Stress		-0.06	0.69	-0.12	0.42
Income		-0.30	0.49	-0.09	0.67
Education		-0.44	0.24	-0.56	0.02*
Crime		-0.24	0.98	6.11	0.43
Vacant property		-0.21	0.98	4.55	0.16
Traffic		0.00	0.99	0.03	0.79

Figure 4
NDVI by CSA

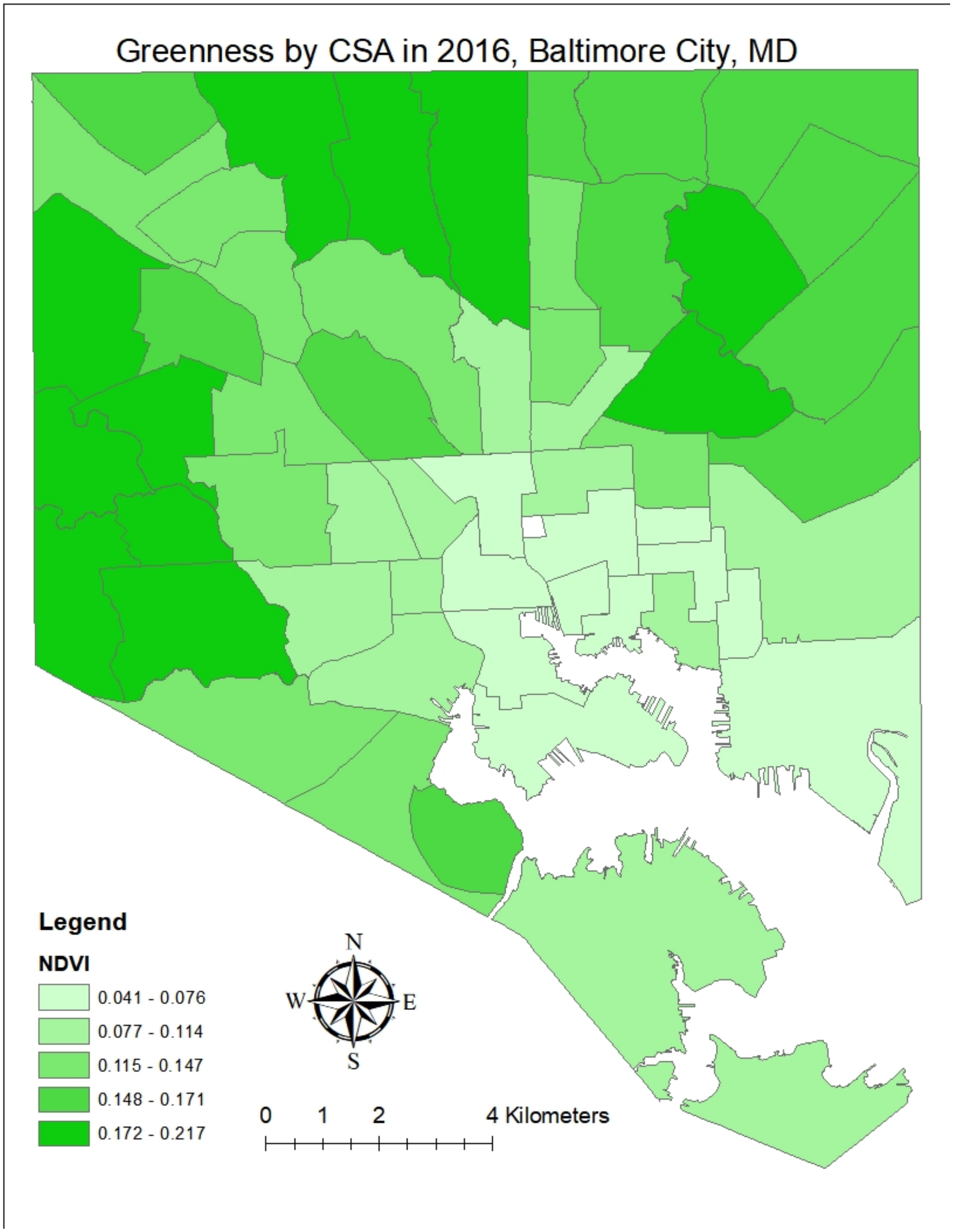


Figure 5
Greenness with Crime

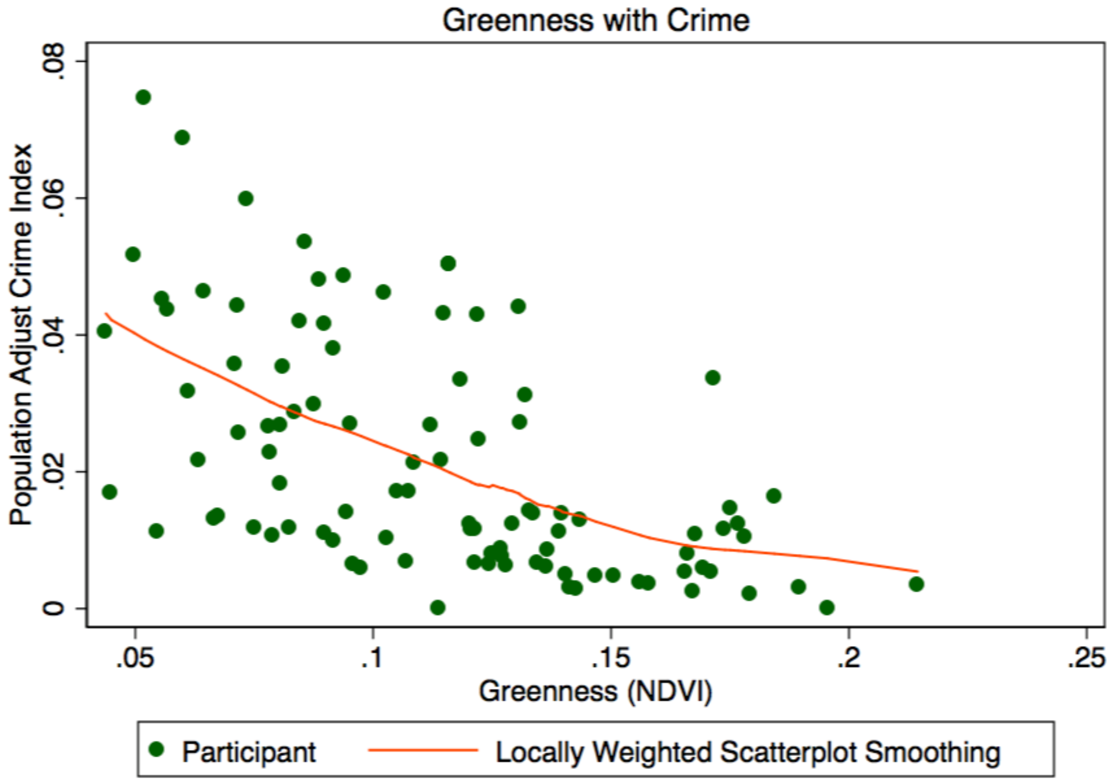


Figure 6
Greenness with Age

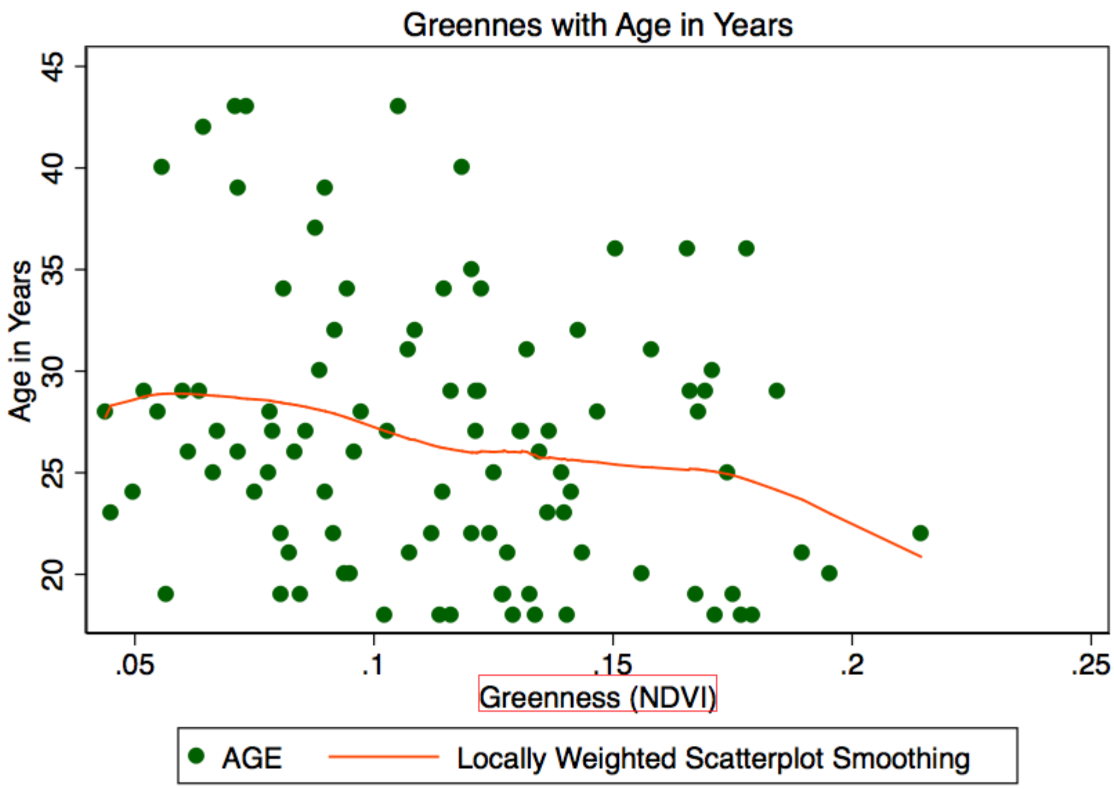


Figure 7
Histogram Transformations

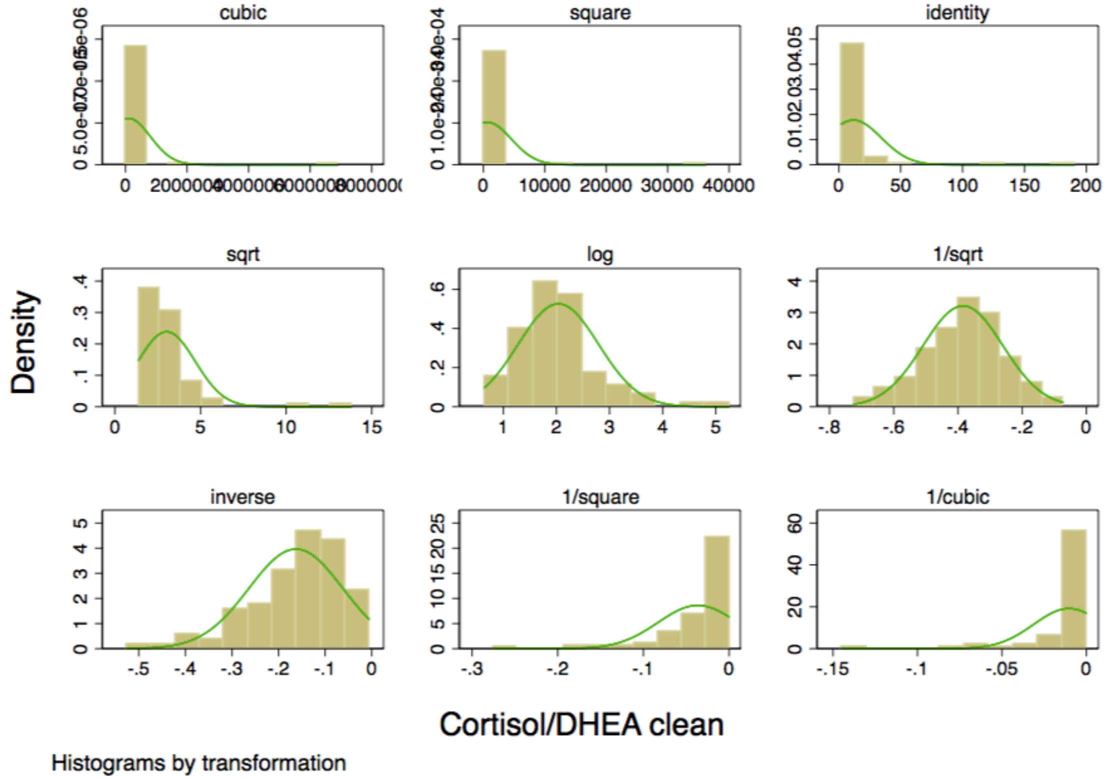


Figure 8
Scatter plot of greenness with log transformed cortisol at waking and lowess line

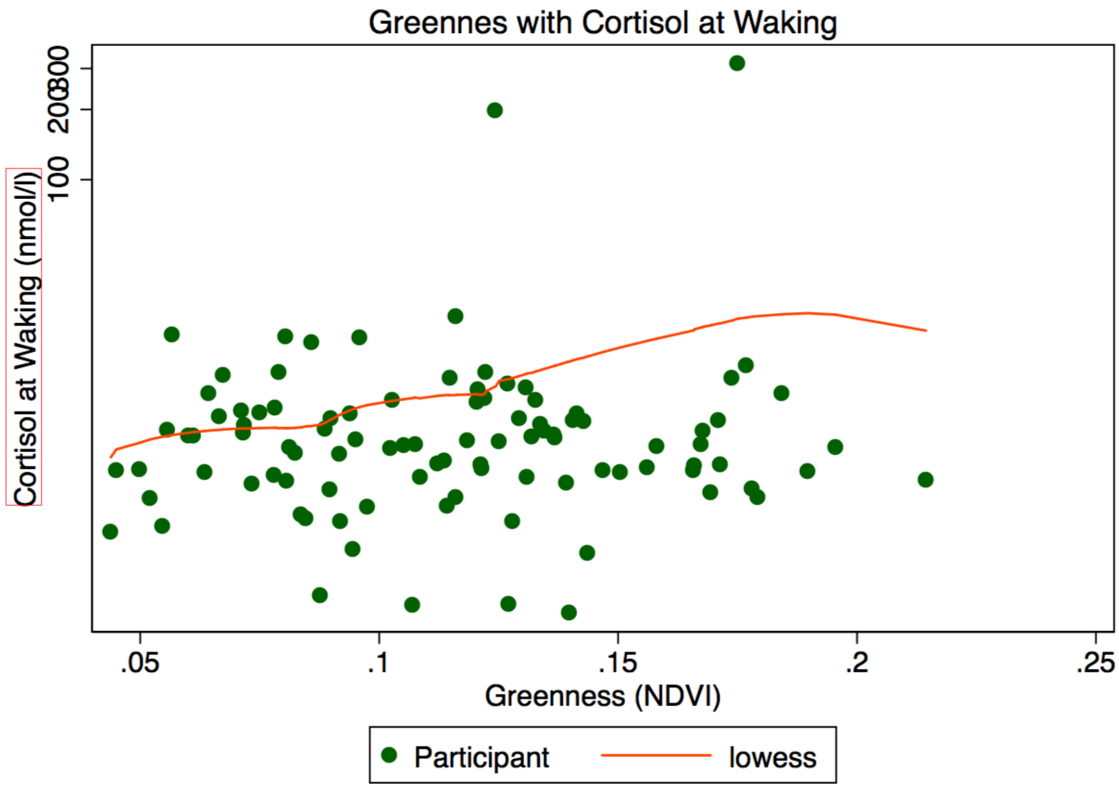


Figure 9
Scatter plot of greenness with log transformed DHEA at waking and lowess line

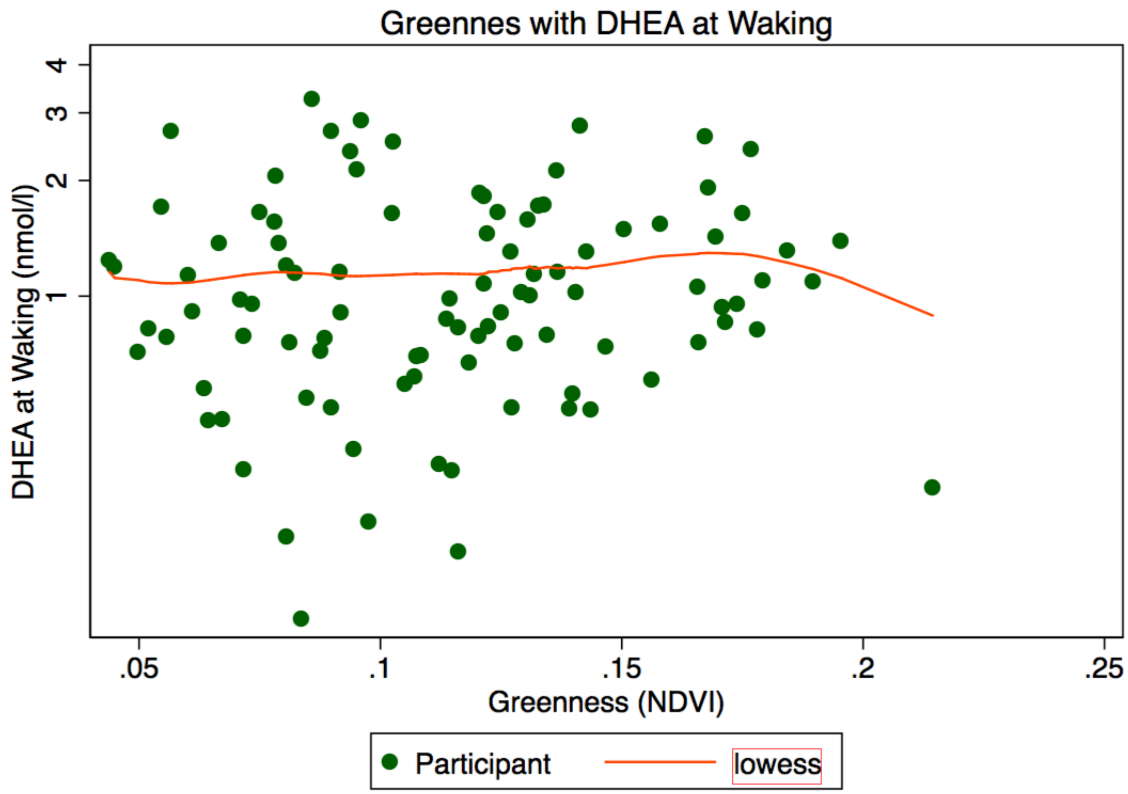


Figure 10
Scatter plot of greenness with log transformed ratio of cortisol to DHEA at waking and lowess line

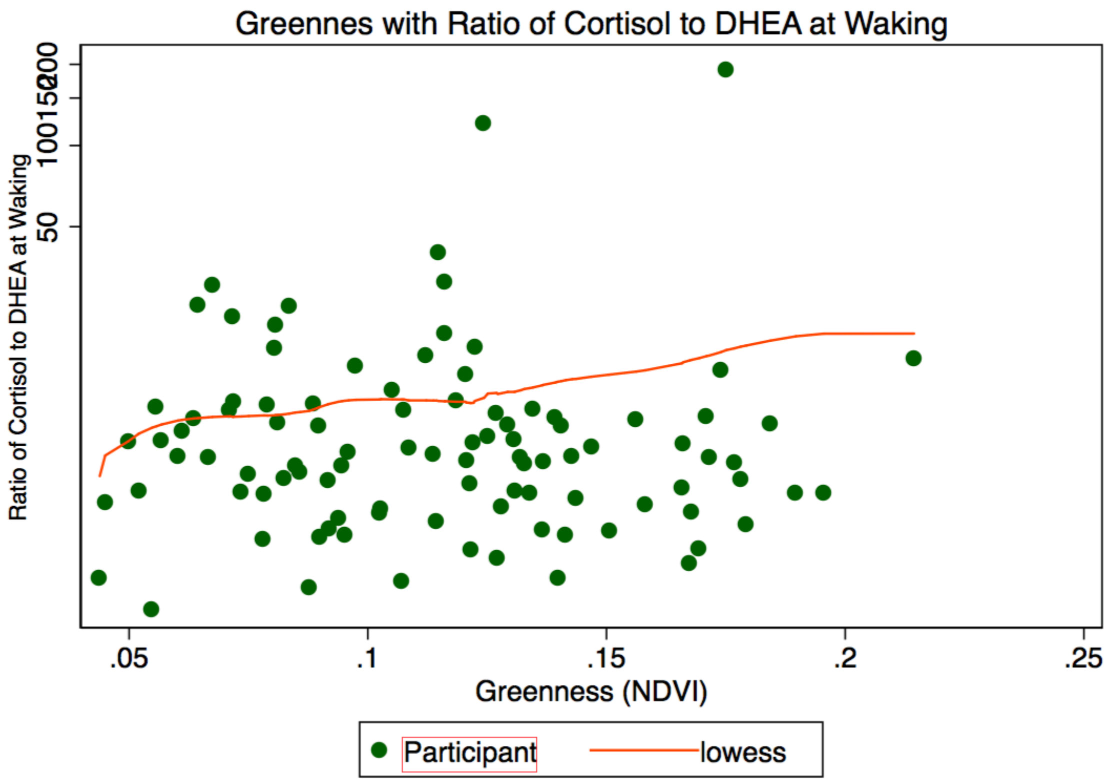


Figure 11
Scatter plot of greenness with cortisol awakening response (n=93) and lowess line

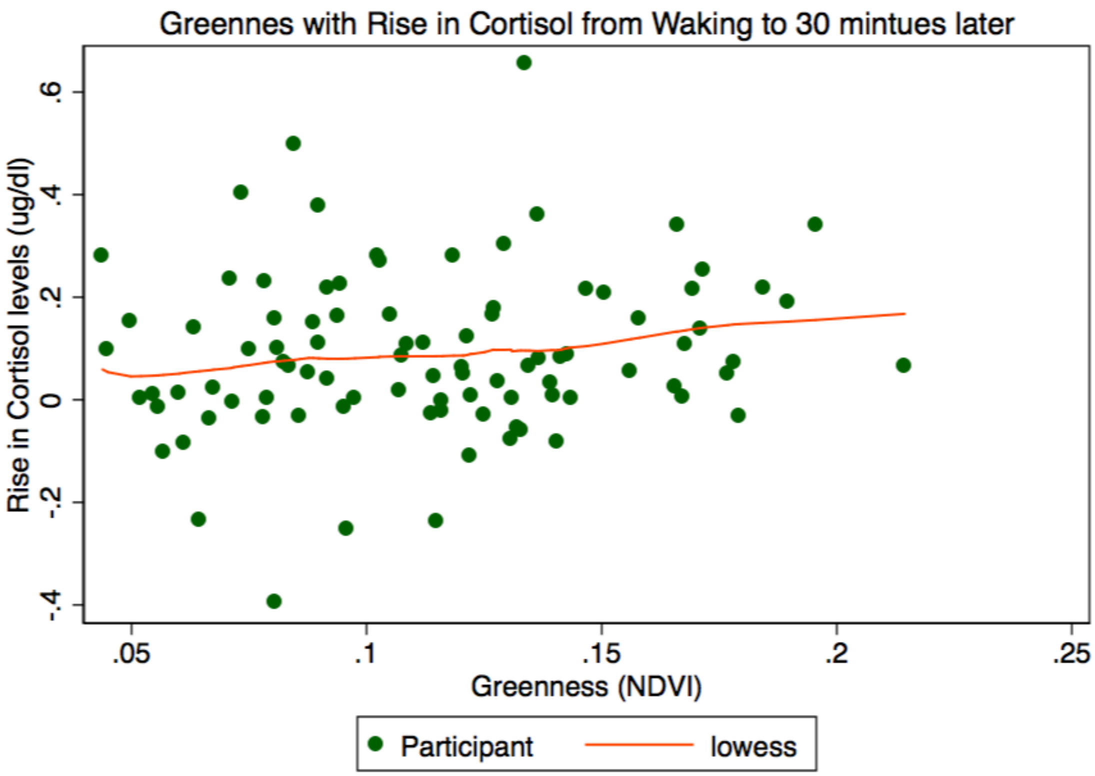


Figure 12
Matrix of scatter plots of greenness and log transformed ratio of cortisol to DHEA in Maddison-East End & Penn North-Reservoir Hill CSAs

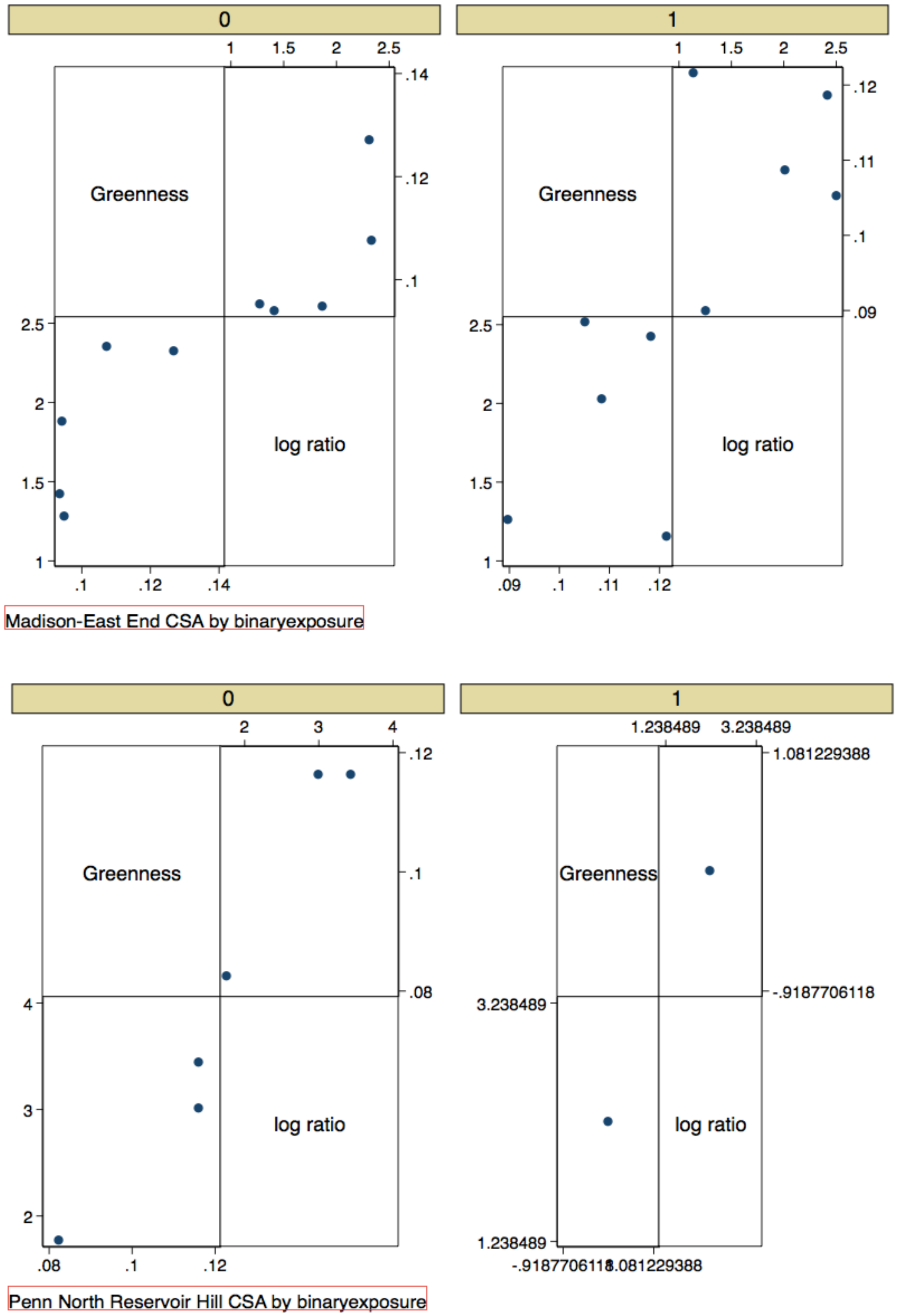
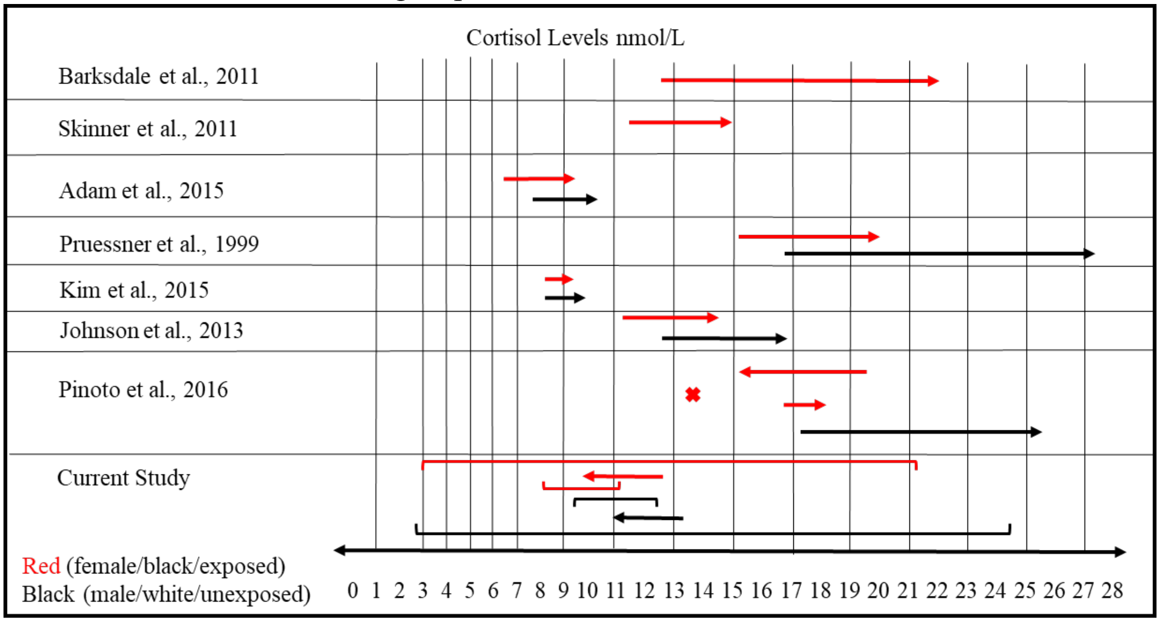
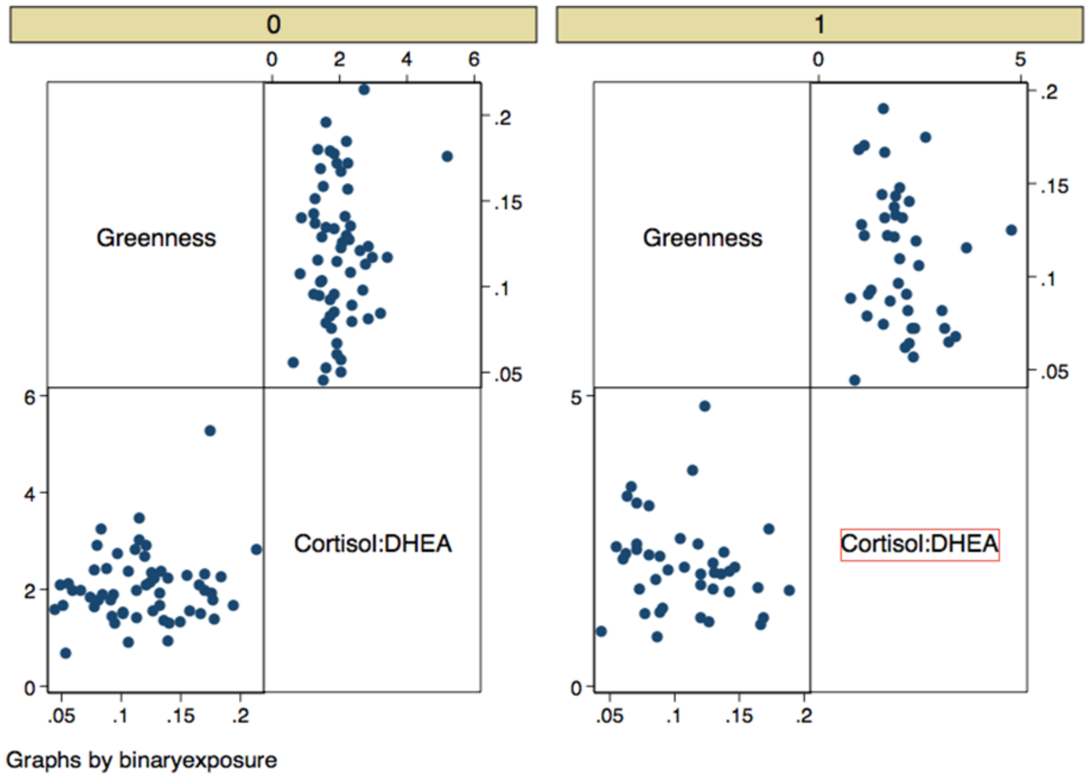


Figure 13
Cortisol and cortisol awakening response



Barksdale et al., 2011: n=30 African American women (M=36.3, Income 30,124)
Skinner et al., 2011: Black 19-20 year olds (65% Female)
Adam et al., 2015: n=50 Black (64% Female, income $46,000)
Pruessner et al., 1999: Teachers with Burnout and no Burnout (N=64, 65% Female)
Kim et al., 2014: male (n=122, age M=36.33, racial/ethnic minority=11%) Female (n=122n, age M=34, racial/ethnic minority=16%)
Johnson et al., 2007: women living in a Shelter (age 34.3, 48% African American)
Pinto et al., 2016: Women living in a shelter (n=76) & with abusive partner (n=73) mean age=36.38 (21-54) (cortisol levels unchanged, Declined, small rise and large rise)

Figure 14
Scatter plot of greenness with log-transformed ratio of cortisol to DHEA by exposure



CHAPTER FOUR: MANUSCRIPT THREE

Greenness and the resilient potential: “Your neighborhood is being neglected because people don’t care. People with power don’t care.”

Target Journal: Journal of Interpersonal Violence

Key words: Resilience, greenness, environmental injustice.

Abstract

The objective of this study was to understand the resilient potential of urban dwelling African American women living with different levels of greenness. This explanatory sequential mixed method study included analysis of quantitative data from 98 African American women between the ages of 18-44, living in Baltimore City, Maryland, at high risk of HIV, forty-one (41.8%) of whom had experienced sexual violence. Qualitative data included 10 in-depth interviews of key informants (n=7) and exposed informants (n=3) representing communities with high and low levels of greenness, along with historical records, field notes, and images analyzed to understand the quantitative data. Greenness was positively associated with physiological-resilience (the ratio of cortisol to DHEA), as well as promoting feelings of calmness, and yet access and maintenance of green spaces is inequitable. Eight themes emerged from analysis of the interview data that identify barriers and facilitators to potential greenness supported resilience: "Boarded Houses," "High Speed. That's a Problem," "A lot of Crime," "It's beautiful…it's green," "It has a calm to It," "Maintained," "Community Builders," and "You do know when people don't care about you." The environments where people live, work, and play vary across social stratum. The landscapes are vastly different, and there are structural barriers within cities in spaces that are supportive of health and wellbeing. Adaptation of urban environments is central to building the resilient potential of individuals and communities to the increasing risks of violence related to climate change. Interventions are needed to promote the resilience of natural urban ecosystems that support individual and community bio-psychosocial health against extreme stress or shocks that would otherwise compromise well-being and health.

Background

Aggression and violence have been positively associated with climate change and anomalously warm temperatures (Mares, 2013; Younan et al., 2018). Based on predicted changes in global carbon dioxide emissions and their influence on climate change, violent crime related to climate change is predicted to increase by 3% (95% CI, 1.5-5.4) by the end of the century (Hsiang, Kopp, & Jina, 2017). In 2011, the economic costs of violence worldwide were over $10.5 trillion (2018 dollars), with 98% of costs deriving from interpersonal violence and intimate partner violence (IPV) (Hoeffler, 2017).

Vulnerable individuals and communities often live in areas with the least amount of green space (Bennett et al., 2007; Jesdale et al., 2013). Trees and other plants are essential to the homeostasis of the biosphere of the planet and to human health (Pavel & Anthony, 2015; Whitmee et al., 2015). In addition to decreasing noise pollution (Dzhambov & Dimitrova, 2014), trees and plants remove carbon dioxide (National Research Council, 2015) and pollution from the air (Bottalico et al., 2016; Dzhambov & Dimitrova, 2014; Livesley, McPherson, & Calfapietra, 2016), and are especially significant in urban areas where rates of air pollution are often the highest (Olden, 1996).

The greenness of trees and other plants can be remotely measured from space via satellites. By comparing the difference between near infrared (NIR) and visible red (RED) wavelengths of light reradiated from the earth, normalized difference in vegetation index (NDVI) can be calculated (NDVI=(NIR-RED)/(NIR+RED)) (NASA, 2000). The use of NDVI is a validated measure of greenness measuring the amount of chlorophyll in healthy flora as part of the natural ecosystem (Rhew, Vander Stoep, Kearney, Smith, & Dunbar, 2011). The NDVI measure, which we refer to as greenness, is an understudied, but growing area of research, especially in the health sciences. NDVI has been associated with decreased health impacts from climate change, including physiological (e.g., respiratory illness and heat-related illness) (Bottalico et al., 2016; Kundu & Stone, 2014; Olden, 1996; Petkova et al., 2014) and psychological (e.g., depression and stress) (Portier et al., 2010; Watts et al., 2015). Greenness has also been associated with resilient mental health among a representative probability sample of Wisconsin Residents (85% non-Hispanic white) and among children living with poverty (ages 3-5) (Flouri, Midouhas, & Joshi, 2014). Furthermore, greenness has been linked to increased physical activity (de Vries, van Dillen, Groenewegen, & Spreeuwenberg, 2013; Jongeneel-Grimen, Droomers, van Oers, Stronks, & Kunst, 2014; Loptson, Muhajarine, & Ridalls, 2012), decreased obesity (Lovasi et al., 2013; Suglia et al., 2016), improved birth outcomes (Hystad et al., 2014; Kihal-Talantikite et al., 2013), decreased urban heat islands (Zhang, Wu, & Chen, 2010) and their effect on heat related illness (Chuang & Gober, 2015). Despite accumulation of stressors, there is little known about how different groups perceive green spaces, what barriers exist in accessing green spaces, and what are the potential benefits of green spaces.

Resilience has been conceptualized as a protective factor for individuals or communities to prepare for, avoid, and adapt to negative social, psychological, and biological consequences of extreme stress or shocks that would otherwise compromise their physical and mental health (Petros, Opacka-Juffry, & Huber, 2013; Szanton & Gill, 2010). Increased exposure to greenness has been associated with resilience as a protective factor against many of the psychological stressors faced by African American women, including psychological morbidity (i.e., anxiety, and depression) (Astell-Burt, Feng, &

Kolt, 2013; Guite, Clark, & Ackrill, 2006; Nutsford, Pearson, & Kingham, 2013). Exposure to higher levels of greenness has been associated with lower incidence of cardiovascular disease (Li et al., 2011), respiratory illness, liver cancer, kidney disease (James, Hart, Banay, & Laden, 2016), and lower rates of violence and crime (Garvin, Cannuscio, & Branas, 2013; Kondo, South, Branas, Richmond, & Wiebe, 2017). A positive relationship between temperatures and aggressive behavior was diminished by greenness (Younan et al., 2018). Environmental inequities intersect as a disproportionate burden on the morbidity and mortality among African Americans (Perry et al., 2013). Institutionalized discrimination has created a urban typography where 61.8% of urban-dwelling Blacks live on block groups with greater than 50% impervious surfaces and 34% have no tree canopy (Jesdale et al., 2013).

Physiological resilience is the body's ability to physiologically adapt to stress (Petros et al., 2013, Russo, Murrough, Han, Charney & Nestler, 2012; Szanton & Gill, 2010). The physiological resistance to stress is a complex interaction among systems to support allostasis (Egorov et al., 2017; Rogosch, Dackis, & Cicchetti, 2011). Allostasis is the synergism of mechanisms responding to changes in the internal and external environment of the organism (Ramsay & Woods, 2014). As stress on the physiology increases, the load on the systems supporting allostasis lose their ability to respond, resulting in an allostatic load detrimental to health and wellbeing and increasing risk of illness and disease (Egorov et al., 2017; Rogosch et al., 2011).

The highest levels of greenness, measured by NDVI, have been associated with a 37% reduction in allostatic load (95% CI -0.46 to -0.27), 54% lower odds of having Dehydroepiandrosterone (DHEA) in the bottom 10th percentile (Egorov et al., 2017), and non-significant lower levels of cortisol 3-hours after waking (Roe et al., 2013). The ratio of Cortisol to DHEA has been suggested as a potential biomarker of physiological resilience (Petros, Opacka-Juffry, & Huber, 2013; Walker, Pfingst, Carnevali, Sgoifo, & Nalivaiko, 2017).

The mechanisms of the effect of greenness on health and resilience are not fully understood. Potential pathways of greenness that influence physical and psychological states and behavioral conditions include the mitigation of noise pollution, heat and the creation of natural sounds, sights, and spaces (Berman, Jonides, & Kaplan, 2008; Irvine, Warber, Devine-Wright, Gaston, 2013; James, Hart, Banay, & Laden, 2016; Kuo, 2015). The built urban environment causes people to be *actively engaged* due to the potential threats there environment may cause (i.e., crime, traffic). On the other hand, nature *passively engages* people, potentially decreasing mental fatigue and restoring one's ability to focus (attention restoration), by providing relief from the built urban environments (Berman, Jonides, & Kaplan, 2008; Kuo & Sulivann, 2001). Additionally, natural green spaces may also support social interactions (Sullivan, Kuo, & DePooter, 2004).

Despite some initial studies finding a positive association between greenness and resilience (e.g., mental wellbeing) among children and non-Hispanic whites, (Beyer et al., 2014; Chawla, Keena, Pevec, & Stanley, 2014; Flouri et al., 2014), little is known about the impact of greenness on resilience of African American women, within the context of the built and social environment of urban neighborhoods. The aim of this study was to understand the resilient potential of urban-dwelling African American women living in different neighborhoods with varying levels of greenness.

Methods

For this explanatory sequential mixed method study (Creswell & Clark, 2011), both qualitative and quantitative data was important to our understanding of the natural ecosystem, specifically greenness of communities, and the resilience of community members of Baltimore City, Maryland, a majority (64.4%) African American city (US Census, 2010). This research began with the exploration of the city itself, and literature on its history that influences the built and social environment today. The lead author, a cisgender male of northern and southern European ancestry was a member of a research team exploring associations of environmental and physiological factors with sexual assault and HIV risk among Black and African American women living in Baltimore City, between the ages of 18-44 ($\bar{x}$ = 26.67, SD=6.64) (NIHG R01HD077891, J. Stockman PI). While recruiting at Baltimore City Health Department clinics, the lead author observed differences in the amount of vegetation throughout the city, an element of the environment not included in the primary study. The observations were supported by exploratory data analysis through geographical mapping of neighborhoods in Baltimore ranging from 0.041to 0.22 (see Figure 15) in terms of normalized difference in vegetation index (NDVI), a validated measure of vegetation (Rhew et al., 2011). This led to an exploration of the literature and an integrative review of green space and neighborhood violence (Mancus & Campbell, 2018).

The quantitative analysis (Mancus et al., nd) used survey and salivary data, both collected in the primary study. Participant addresses were geographically coded in ArcGIS 10.4.1 (ESRI, 2015) and joined with geospatial data from publicly available environmental data from local and federal sources, including the City of Baltimore,

Baltimore Neighborhoods Indicator Alliance (BNIA, 2016), U.S. Environmental Protection Agency (US EPA, 2014), and the U.S. Geographical Survey (USGS, 2016). With all the gathered data, data embedded maps layers were created in ArcGIS 10.4.1 to identify the differences in the social and built environment of Baltimore City (see figure 15-19). Additionally, to contextualize the quantitative findings, data from multiple sources was used: 1) aerial and ground level images for specific areas of the city were analyzed in combination with 2) in depth qualitative interviews of purposively sampled key informants (KI) and "exposed" informants (EI), 3) field notes, and 4) historical records of Baltimore. "Exposed" informants (n=3) were primary study participants who reported sexual violence and lived in neighborhoods within community statistical areas from the highest quintile (NDVI scores between 0.15-0.21) and lowest quintile (NDVI scores between .043-.078). Key informants (n=7) were purposively sampled from the same community statistical areas (CSA) including Penn North-Reservoir Hill (highest quintile) and Madison-East End (lowest quintile).

Data Collection and Sampling

Recruitment of participants for the quantitative portion of this study took place at the Druid and Eastern branches of the sexually transmitted infection (STI) clinics of the Baltimore City Health Department. Female clients of the clinic were systematically sampled, and willing participants were screened for eligibility. Inclusion criteria for the quantitative data analysis included: self-identification as a Black or African American woman, between the ages of 18-44, living in Baltimore City, Maryland, and at high risk of human immunodeficiency virus (HIV) from their own but primarily their intimate partners behaviors (for details see Stockman et al, ND). For the quantitative analysis of the current study, participants were required to have salivary samples for two days with Cortisol and Dehydroepiandrosterone (DHEA) at waking and an address that could be geographically coded. HIV risk criteria included one or both of the following: (1) two or more unprotected sex partners (mean = 3.01, SD=3.06), or (2) sex with a high-risk partner (n=87, 89%) (mean = 2.66, 95%CI 2.29,3.03); partner intravenous drug use (n=15; 15%), partner non-intravenous drug use (n=15; 15%), male partner who has sex with men (n=40; 41%), partner who cheats (n=77; 79%), partner has sexually transmitted infection (n=54, 55%), partner was in prison (n=34, 35%), or partner is HIV positive (n=26, 27%). Eighty-nine percent of the women in the primary study reported having a partner with HIV at-risk behaviors. Forty-one women (41.84%) reported sexual violence as adults, 32 (78.05%) of whom experienced sexual violence as a child.

Sampling for the qualitative interviews began with participants recruited for the parent ESSENCE Study who were among the exposed group ("Exposed" informants – EI) representing the highest and lowest quintile of NDVI values of the study. Key informants (KI) were purposively sampled from community organizations in Baltimore City community statistical areas of Penn North-Reservoir Hill and Madison-East End. Inclusion criteria for the qualitative data included participants who could speak of the social and built environment of Middle-East End or Penn North-Reservoir Hill CSA and were at least 18 years of age. The lead author participated in three of the in-depth interviews with participants who reported sexual violence for the qualitative portion of the ESSENCE Study (EI).

The exposed informants all reported sexual trauma including adult forced sex, gang rape, adult stranger rape, and partner sexual abuse. The exposed informants were between ages of 20-30, similar to the study as a whole (M=26.7, 95% CI [25-28]. The median number of people exposed informants reported unprotected sex with was two, and partner risk behaviors was 1 (max=4). The median crime within 100 meters was 22, and traffic proximity and vacant properties were both in the highest quintiles. Key informants included young (n=4) and middle-aged adults (n=3). Key informants were not asked about sexual violence and none disclosed any experience of sexual violence. Even so, since over thirty percent of women in the USA report physical or sexual violence by an intimate partner and/or sexual violence from others (Smith et al., 2010), there is the potential that at least two of the Key Informants experienced violence from a partner.

Field notes were collected in the exploration of the community statistical areas where both qualitative (EI) and quantitative (KI) participants lived using satellite images (Google Inc, 2018), street views (Google Inc, 2018) and walking through neighborhoods (Nicholls, 2017). Walking through the neighborhoods, visiting churches, community gardens and barbershops, facilitated connecting both to the space and engaging the representatives of community organizations in these areas of Baltimore. These representatives were recruited as key informants for the in-depth interview (n=2). Additional recruitment of (n=5) key informants came through existing networks and through snowballing (Turley, Saith, Bhan, Rehfuess & Carter, 2013).

Interviews with exposed informants (EI) began with initiation of a conversation through a grand tour question, “How would you describe your current environment and neighborhood?” to facilitate participants telling their story (Corbin & Strauss, 2007). Follow up questions asked about living situation, stress, relationships, violence, services provided and areas they would like to see improved (see Appendix A). The grand tour question to key informants (KI) was, "How would you describe the current green spaces in your neighborhood?" Additional questions about green space included history, activities, access, and the impact of greens spaces on health and behavior (see Appendix B).

After conducting the initial three interviews, the neighborhoods were visually explored from satellite view and street view in Google Earth Pro (2018). We identified parks that participants discussed in their interviews as well as green spaces, including urban forests that were not identified by participants. This led us to ask more specific questions about the barriers and facilitators in accessing green spaces. The key informants came from neighborhoods within the community statistical areas in Baltimore that came from the highest (Penn North-Reservoir Hill) and lowest (Madison-East End) levels of greenness of the addresses of the quantitative sample, and within walking distance of the Baltimore City Health Departments. Recruitment continued until saturation of themes.

A Brief History of the Neighborhoods and Communities within Baltimore City

Within the history of the United States, there is a complex story that sets the stage for events that occurred over time in Baltimore. This includes slavery, emancipation, segregation, and the ongoing systematic institutional oppression and unconscious bias that manifest as the terrain of Baltimore and the larger United States (Elfenbein, Hollowak & Nix, 2011; Power, 1983). Per the 1810 census, there were 52,172 people living in Baltimore City, from which 5,617 were "other free persons" (free Blacks, Native Americans and immigrants from Asia), and 4,672 "slaves" (Maryland State Archives, 2018). Per the 1860 census, there were 25,680 "Free Blacks" and 2,218 "Enslaved" out of

212,418 people living in Baltimore City (Maryland State Archives, 2018). By 1880, post-Civil War, the census listed 53,716 “colored persons” in Baltimore City. Baltimore was not segregated by law prior to 1910. However, starting in 1910, segregation laws were enacted and struck down multiple times by legal precedent (Power, 1983).

The National Housing Act of 1934, along with the actions by the Federal Loan Bank Board and Home Owners Loan Corporation (HOLC), institutionalized segregation and inequality by drawing lines of different colors (see Figure 15) on a map (Gotham, 2000). Since then, these lines, especially the yellow and red lines have disproportionally impacted predominantly Black and African American communities in terms of access to housing, investment, loans and grocery stores (Eisenhauer, 2001). The placement of health care services (Eisenhauer, 2001) and the building of highways (Sugrue, 2014) has also been a result of the interpretation of residential security by investors and banks. Areas of urban cities and suburbs across the U.S., including Baltimore, were graded highlighting the “*best*” investments in green colored lines (see Figure 15) (Greer, 2013). Wealthy suburban neighborhoods at the time, like Roland Park (established in 1891) in Baltimore City, segregated by covenant and deeds, were deemed “*best*” for investment (Pietila, 2010). Neighborhoods with immigrants from eastern and southern Europe were marked with yellow lines for “*declining.”* The “*hazardous”* areas for mortgage investment were marked in red colored lines and were predominantly Black neighborhoods (Zenou & Boccard, 2000).

The post-World War II Servicemen’s Readjustment Act of 1944 helped over two million veterans finance homeownership (US Veterans Administration, 2013), fueling increased suburbanization (Stahura, 1986). Structural and unconscious bias steered white soldiers to the suburbs while Black and African American soldiers were often denied benefits (Onkst, 1998). Furthermore, the Federal Aid Highway Act of 1956 increased the number of highways conveying suburban residents to city centers across the country. Highways cut through red and yellow lined neighborhoods (DiMento, 2009). In 1956, the city of Baltimore began the construction of Interstate 83, a 6-lane highway within 100-feet of yellow lined homes (Kelly, 2009). Additionally, what was to be Interstate 170, now named the "highway to nowhere," is today a 1.9-mile section of US Highway 40 (see Appendix D) cutting through what were yellow lined neighborhoods (Harlem Park Neighborhood), predominantly home to Black and African Americans, displacing 1,500 people, destroying 971 homes, and 62 business in 1974 (DiMento, 2009; Gillispie, 2018; Lopez, 2012).

The 1.9-mile section of highway starts and ends with city streets, dropping down below street level in what can be described as a "canyon" (see Appendix E). This project was to be a direct connector from the east to west had opposition in the eastern neighborhoods of Baltimore not stood in the way (Gomez, 2012).

Baltimore City community statistical areas (CSA) (n=55) are statistical areas in a size between census tracks (n=200) and zip codes (n=21). The CSAs are guided by neighborhoods (n=271) that allow for the census data to be contextualized by space people can identify (Johnson Thornton, Greiner, Fichtenberg, Feingold, Ellen & Jennings, 2014). Penn North-Reservoir Hill (PN-RH) and Madison-East End (M-EE) CSA's are 2 of the CSAs in Baltimore City that live today with the implications of these inequities. For additional context, two other CSAs, Roland Park-Popular Hill (NDVI=0.18) and Charles Village-Barclay (NDVI=0.1), are highlighted throughout.

Penn North-Reservoir Hill and Madison-East End represent the top and bottom quintile of greenness for the quantitative analysis in the quantitative sample, respectively (See Figure 16). For additional zoomed-in views of all mentioned CSA, (see Appendix F).

Penn North-Reservoir Hill, located on the northwest side of Baltimore, encompasses Penn North neighborhood (Baltimore City Department of Planning, 2006) and Reservoir Hill neighborhood (Reservoir Hill Improvement Council, 2001). Reservoir Hill was rapidly developed from the late 1800's through the turn of the century. The neighborhoods that make up the Madison-East End include all of Milton-Montfort, Madison, and East End neighborhoods, as well as parts of McElderry Park, Elwood Park, and Middle East.

In 2010, Blacks or African Americans were 13.8% of the population in the US (Baltimore Neighborhood Indicators Alliance, 2016). However, the majority of residents in Baltimore City are African American or Black; yet the diversity index (probability that two randomly selected individuals having same ethnicity/race) varies throughout the city and over time (see Table 8). The largest changes in demographics in Madison-East End were among people who identified as Hispanic (4% to 9.4%) (BNIA, 2016). In Penn North-Reservoir Hill, the largest demographic increase was among those who identified as non-Hispanic white (5.7% to 9.9%) (BNIA, 2016).

Results: Themes

After transcribing interviews verbatim, the lead author and interviewer immersed himself into the transcripts. Data were fractured to determine information contained in individual interviews (Chen & Boore, 2009). Threads of data among different sources were tied together and eight themes emerged. The themes about barriers to access to green spaces came directly from participant quotes, including “Boarded Houses” (vacant property), “High Speed. That’s a Problem” (traffic proximity), “A lot of Crime,” “It’s beautiful…it’s green,” “It has a calm to It,” “Maintained,” “Community Builders,” and “You do know when people don’t care about you.”

“Boarded Houses”

In 2016, there were 16,634 vacant properties in Baltimore City (see Table 9), with heaviest concentrations in yellow lined and red lined community statistical areas (BNIA, 2016) (see Figure 17). While properties are legally vacant, they are not necessarily empty:

“You can go to some communities in Baltimore and see literally squatters rising up out of abandoned buildings. As well as people just hanging on the corners. If you move towards Penn North, there are a lot of people sitting on the steps of empty houses. African-American men in particular on the steps” (KI 6 PN-RH CSA).

In Madison-East End, vacant properties were more than twice the proportion in Baltimore and accounted for 4% of the city as a whole. One reason for percentage of vacant property drop in Madison-East End was property demolition (BNIA, 2016) (see Table 10). Demolition permits in Madison-East End were 2-3 times higher than Baltimore City as a whole (BNIA, 2016).

Vacant property demolitions remove dilapidated eyesores, but result in vacant lots that can become depositories for “trash” (KI 2 M-EE CSA). Community members have transformed some of these vacant lots and central blocks into parks and gardens (see Appendix G), as descried by a key informant of Madison-East End: “We have been working on turning 108 vacant lots into green spaces” (KI 2 M-EE CSA).

Among participants in the quantitative analysis, there were on average 8 vacant properties (95% CI 6-11) within 100-meters (about the size of a typical block in

Baltimore City) of their home. Rates of demolition in Penn North-Reservoir Hill are similar to Baltimore City as a whole (BNIA, 2016), in spite of having a higher percentage of vacant buildings. The percentage of permits for the rehabilitation of buildings in Penn North-Reservoir Hill has been consistently higher than Madison-East End (see Table 11).

Vacant prosperities and the rehabilitation of homes in Penn North-Reservoir Hill is described by a key informant as follows:

"I will say that there has been a lot of change in terms of housing, they're a lot more of boarded houses, but this neighborhood has had a period where the downed homes, where people were buying houses and re-habiting which we were a part of. And then the drugs scene in the 80's and people started losing homes, and we started seeing a downturn. And then, I would say, probably in the last 10 years, 5 to 10 years, there has been a change for the better and some of those houses that have been boarded for years are now being redone and people are moving back in to build again" (KI 6 PN-RH CSA).

"High Speed. That's a Problem"

In 2016, sixty percent of Baltimore City residents drove alone to work (BNIA, 2016), and additional 217,235 commute from surrounding counties and states into the city to work (see Figure 18). Commuter traffic from northwest and west suburbs come into the city mainly on Interstate 83 and Highway 1, which go by Penn North-Reservoir Hill. The commute from east and northeast suburbs is funneled from Interstates 95 and 895 onto Highway 40 (Orleans street) and Madison Street, which go by and though Madison-East End.

In spatial analysis we found traffic proximity for participants in Penn North-Reservoir Hill to range from the 92nd to 93rd percentiles for the country. Traffic proximity for Madison-East End was in the 82nd percentile. Traffic proximity from all participants (n=98) in the quantitative analysis was above 77th percentile for the United States (95%

CI 74.6, 80.81). The impacts of above the average traffic proximity for residents of Madison-East End, as compared to overall Baltimore and the United States, is tangible:

"Cars go by and that's a problem. Sometimes they zoom down here, and what happens is that they come off Orleans street because all the streets are going out the city and coming in, except for a couple of the alley streets. They make their left off Orleans street to come into the community. They are going 40, 50 miles an hour on Orleans street and now they turned onto this small street and they are still in that high speed. That's a problem" (KI 2 M-EE).

"A mile is definitely a trek, you have to cross [the street], it's not safe (…) When you think about things like traffic and distance and time and element, it makes you think twice. And I think, very often, the idea of all the barriers makes you not wanting to do it" (KI 7 M-EE).

In 2016 there were 1,226 collisions between cars and pedestrians in Baltimore City, accounting for 36% for entire state of Maryland (Maryland Department of Transportation, 2017). Among those collision, 1,082 resulted in the pedestrian being injured and 17 people died from those injuries (Maryland Department of Transportation, 2017).

"A lot of Crime"

Between 2010 and 2016, there had been a 16.1% reduction in all crime and a 4.5% decrease in violent crimes in the United States (FBI, 2016), while in Baltimore City (see Figure 19) there was a 3% increase in all crime and 11% increase in violent crime (see Table 12) (BNIA, 2016). In Penn North-Reservoir Hill, crime rates per 1000 residents increased 4% between 2010 and 2016, whereas violent crime decreased by 15% in the same period.

In Madison-East End crime and violent crime rates increased 25% and 10 percent, respectively, from 2010 (BNIA, 2016), 1.5 times the city average. In the course of meeting key informants, changes in in Penn North-Reservoir Hill were described as "the crime has increased, the people, population, houses are congested" (KI 4 PN-RH).

Among our quantitative participants, there were on average 17.9 crimes (95% CI 15-21) and 7.98 (95%CI 6.4, 9.5) violent crimes committed within 100-meters of their home. Penn North-Reservoir Hill key informants described the impacts of crime:

"There is an area, two streets over, that had apartments there, there was a grocery store. A fairly bustling area but became what they call a 'murder mall.' Unfortunately, there was a lot of crime, a lot of going on there, to the point where they actually just shut it down." (KI 6 PN-RH).

"Dirt, trash. It's not very clean. And also, probably around Druid [Hill Park], probably not very safe for anyone at all, especially kids and women. It's not very safe. There are a lot of people outside screaming here and there, fights sometimes. I have never seen a gun, but I do hear people fighting" (KI 3 PN-RH).

The Madison North Park Apartments in Penn North-Reservoir Hill (see Figure 16), referred to by KI 6 and the Baltimore Sun newspaper as "Murder Mall," was torn down in 2016 (Wenger, 2016), and is as of yet awaiting redevelopment according to field notes on June 20th, 2018.

In Madison-East End, where the crime rate was the highest, the most significant impact of crime on green space was shared as, "They got a new fence because people where growing the food and then people start coming and stealing all the food" (KI 2 M-EE).

Furthermore, the lack of visibility from trees and bushes has an impact on people's perception of the safety, both during the day and at night:

"A bush I can't really see what's there. Like I said, it can be a habitat by anything, creatures big and small" (KI 7 M-EE).

"There's so many trees and it's beautiful in the daytime, but it's dark at night. We have lights along here, but they are like cozy lights. There are enough spaces around here for people to hide" (KI 6 PN-RH).

“It’s Beautiful…. it’s green”

When asking key informants about green spaces in their neighborhoods, a common response was to talk about parks and playgrounds: “Patterson Park, which is the closest one” (KI 6 M-EE) and “most of the parks in my neighborhood, they have the playgrounds” (KI 4 PN-RH). Key informants and exposed informants talked about their own enjoyment of parks: “it’s fun” (EI 3 PN-RH), "It’s a need” (KI 7 M-EE), and playgrounds for children “so that he can have fun, cause he’s a child” (EI 2 PN-RH), and “it was gorgeous for the kids to play” (KI 4 PN-RH-).

We found Statistical Areas in Baltimore having an average greenness (NDVI) that range from 0.0041 to 0.22 (see Figure 5) when excluding waterways, as the NDVI range for water is approximately -1 to -0.1. We found Penn North-Reservoir Hill to be in the fourth highest quintile of greenness of the city (see Table 13).

In Penn North-Reservoir Hill there is a large historical park named Druid Hill Park. One key informant describes this park as follows:

“It’s beautiful. So that is what I think when I think of this neighborhood, it’s green. I call Druid Hill Park my backyard because that is what I feel like. There are lots of flowers and I love to walk in the Spring when things are blooming, and to see all the different flowers in the neighborhood. And then Druid Hill Park is also just green, that’s what I think of, very pretty” (KI 6 PN-RH CSA).

Participants from Penn North-Reservoir Hill in our quantitative analysis greenness ranged from 0.08 to 0.112, below the mean of our study (mean=.114, 95% CI 0.043, 0.21) and the CSA as a whole. Measurement of greenness in Baltimore changes from block to block and neighborhood to neighborhood. Highlighted by the following quotes:

“The greenness has been pretty consistent I would say. I guess just some context: I am here in this street now, but I grew up probably on two or three streets over. There was a playground, there were plants and flowers and things outside, but it was more concrete then than green, like you see right here but we still [had] Druid Hill park, we could go there and play. That hasn't changed" (KI 6 PN-RH).

"It's mostly like residential, there's no real green space around. It's like house after house where I live. So, there's no real space" (EI 1, PN-RH).

In Madison-East End, the average greenness is in the bottom quintile for Baltimore (see Table 13). One key informant that lives in East Baltimore described the lack of land as "the city is constructed in a way to maximize housing. I think with that you reduce the amount of land, green space area that is available" (KI 7 M-EE CSA). In comparison Madison-East End has double the land per person of Baltimore city as a whole and an eighth of the land of RP-PH CSA (see Table 13). Roland Park-Poplar Hill CSA (see Figure 16) is located in north-central Baltimore and has a greenness score in the top quintile for the city (see Table 13), similar to Penn North-Reservoir Hill, but twice as much land per person. Population density is a challenge highlighted by one key informant who described a community survey asking for "more parks" and "everyone wanted a lot of green spaces, like parks" (KI 2 M-EE).

"It has a Calm to It"

As greenness, traffic, vacant properties, and crime are not equally distributed in Baltimore, we explored the relationship between greenness and resilience (operationalized as the ratio of Cortisol to DHEA). Among the participants in the quantitative analysis, we found at 100-meters a negative association (β=-0.246, p<.01) for adjusted for population crime with greenness. When we disaggregated crime, we also found a small negative association for aggravated assaults (β=-0.03, p<.01) with greenness. One possible mechanism described by key informants is the impact of greenspace on behavior of children working in the community garden: "I think they have fun, a lot of fun, they work together, brought them together. I think that was a positive effect on their behavior" (KI 2 M-EE).

In the full model, accounting for clustering at the community statistical area, we found for every 1 standard deviation (.039) increase in greenness there was a 34% ($p<.05$) increase in resilience (operationalized as the ratio of Cortisol to DHEA). We hypothesize that, amongst this highly stressed group, higher levels of greenness where participants live is protective against negative effects of their stress response. In qualitative data, green spaces and nature were identified as having a calming effect:

"I think it has a very healing effect. Physically is good for exercise, is number one. Keeps you active, moving around, bending down, digging. When you are nurturing something, I think psychologically has a benefit in that way, from the mental health. Through that kind of nurturing, watching someone grow. And then just the physicality of the space: its cooler, things move in the wind, you hear the birds chirping, you see beautiful flowers blooming. It's very relaxing. It's very relaxing environment to be in" (KI 2 M-EE-CSA).

"Maintained"

Care, or the lack of it, can transform green spaces, whether it is in a park, the neighborhood in general or dumping in vacant lots:

"When you live in a poverty environment, it affects the children, and affects people's moods and all that, versus you living in a well clean neighborhood, everything is well kept, people will be more refreshed" (KI 5 M-EE CSA).

"It was a liability because people were dumping constantly, even somebody was found dead in this space. And then there was tons of rats, and trash. People would dump their stuff in the vacant lots because nobody was taking care of them. They thought it was free range, kind of a thing, so you didn't have to pay money to dump" (KI 2 M-EE-CSA).

Hazardous materials are also found in green spaces including the vacant properties created by demolition. Some materials identified were lead, broken concrete, and bacteria (KI 2 M-EE). Concrete is a barrier to the growth of green space and its use: "Kids said they wanted a place to play ball, but, there was a lot broken concrete, and all this stuff in there" (KI 2 M-EE). In 2016, 2.4% of children tested in Madison-East End tested positive for Lead (BNIA, 2016). While some of this may be indoor exposure, aging infrastructures and contaminated soil are also a potential source:

"What happened was a backup of the sewer system. There was leaking out into the grounds and went right through our garden because they had a map of it, and that sewer system when right underneath our garden, there was sewer leakage into the groundwater, and that particular spot" (KI 2 M-EE-CSA).

"The soil was contaminated, it had a lot of lead in it. So they took out all the soil, put down some new soil and then did plantings on the right-hand side, and on the left hand side we planted grass" (KI 2 M-EE-CSA).

"Community Builder"

Madison-East End is in the lowest quintile of greenness; however in the last ten years the community has been engaged in "planting hundreds of trees and bushes, and some perennials" (KI 2 M-EE-CSA). Like seeds, spaces with attention and care can grow:

"It started with coming here and clean up the lot. We started out with just three triangles it started with a vegetable garden. That was the anchor that started the whole thing" (KI 2 M-EE-CSA).

Green spaces within communities are extra living and play spaces for persons of all ages. One key informant from Madison-East End highlighted the extension of living space: "these houses are very small in size, so a lot of people sit outside on their steps all the time because it's fresher" (KI 2 M-EE-CSA). Similarly, a Penn North-Reservoir Hill key informant stated: "People will do what they call, 'stoop nights,' and they bring out wine and hang out" (KI 6 PN-RH-CSA).

The community efforts to create green spaces, gardens, and parks transformed vacant lots into block and neighborhood central community spaces. An example of a central block park as community spaces is described by one key informant as "the kids can play ball there, but it has also turned into this community event space. Some people had some weddings there, where they had the gatherings and reception" (KI 2 M-EE-CSA).

The building of community and resilience through shared spaces, including green spaces, was stated in many ways:

"I think one of the good things about the garden is that it can bring people together, so you have the sense of community; it's a good community builder. People feel connected, they feel ownership of the community around them, and gives the power and a certain strength. Working together in shared spaces transforms the space and the community" (KI 2 M-EE-CSA).

"My idea is that it makes it feel like a neighborhood, somewhere you can walk and feel okay" (KI 7 M-EE CSA).

"And then this one little boy, he was probably about 4 years old (…) and he comes up to me and goes (because his English was a lot better, you know), "we did aaaalllll of this!" with his arms spread out, with such a pride on his face. It brought tears to my eyes" (KI 2 M-EE-CSA).

In Penn North-Reservoir Hill where greenness was in the highest quintile for the city, a key informant emphasized how the environment facilitated connecting with people:

"It has always been a sense of community around here, and I like that. I do need to be careful, my kids need to be careful. I can, for the most part, walk down the street and go, 'how are you doing?' And people are cool, and they will speak back, and they would look out for you without knowing you" (KI 6 PN-RH-CSA).

"You do know when people don't care about you"

In Baltimore City, not all publicly available green spaces are equally funded, as described by the following key informants:

"Similar I think when you are looking at limited funding and addressing this as a need, especially for people that are in the greatest need, to feel like this is sort of a healing, or a calmness space that deserves its budget and attentions" (KI 1 PN-RH CSA).

"You can tell that it is a park, but it has been closed down, I don't know why, but is not in use anymore. There is not a lot of playgrounds or green spaces" (KI 3 PN-RH CSA).

Between 2010 and 2016 income in the United States increased 7%. In Baltimore City, income increased 15%. The median household income increased 23% in Penn North-

Reservoir Hill and in Madison-East End household income declined by 12% (BNIA, 2016). Sixty percent of participants in the quantitative survey reported individual income of less than $10,000 annually, with 81% obtaining high school education equivalency or higher (see Table 14).

For those green spaces under responsibility of the City of Baltimore, the budget for maintenance of those for years 2018 and 2019 are almost flat or dropped. The Baltimore City budget ($2.9 Billion) for the year 2018 is proposed to have an increase of 0.5% for “park maintenance” (0.5% of total) and a 7% increase for “police patrol” (9% of total). The budget for "urban forestry” and “horticulture” decreased by 4% and 5%, respectively. Both the “Right of way landscape management” (i.e., maintenance trees and grassy areas between and along streets) and “traffic safety” decreased by 8% (see Table 15) (Baltimore City, 2018).

City services are supplemented by neighborhood associations, including funds raised by Charles Village Community Benefits District, located within CV-B CSA (see Figure 16) and Guilford association, within the RP-PH CSA. The Charles Village Community Benefits District publicly posts an annual budget of over one million dollars for sanitation, safety, community events, recreational activities, development of green spaces, and promotion of the district, in addition to services the city provides the neighborhood (Charles Community Benefits District, 2017). Roland Park is managed by the Guilford Association. In their annual meeting minutes, Guilford Association anticipated $440,800 in homeowner association’s fees (Guilford Association, 2017). Between 2006 and 2016, $74 million was invested in Reservoir Hill (i.e., reclaiming vacant lots as public spaces, developing greener streetscapes, purchasing housing, marketing, investing in large development projects) with funds from grants (Reservoir Hill Improvement Council, 2016). That $74 million dollars invested in Reservoir Hill amounts to $7.4 million per year or 2.7% of the budget for citywide police patrols and 0.3% of the total city budget in 2018. Even though some CSAs in Baltimore City are able to collect homeowner association fees to improve the surrounding greens paces and built environment, the same is different in other parts of the city, as stated by key informants:

"I think, as an African-American who's woke, that is really frustrating to see because you know that you are being neglected because people don't care. Your neighborhood is being neglected because people don't care. People with power don't care. I think that whether you have lots of degrees or no degrees, as an African-American, you do know when people don't care about you" (KI 6 PN-RH).

"Just look at the crumbling façades on the streets that I don't actually like to drive on which is 40 (…) it's how close we are to these roadways and how close we are to main arteries that are killing our parks and cutting us off (…) they have caused communities to die" (KI 1, PN-RH).

"All of this boils down to economic reason, it depends on where you live because if the community has more money to implement places like playgrounds, and also maintain green spaces then the community, the population and the people who would be able to utilize it, but if you don't have it, the community is not putting in more money, the little that they have is not even maintained then they can't utilize it because is not available" (KI 3 PN-RH).

"I can't see somewhere, like East Baltimore, where the poverty is much worse; I am not sure you are going to take out $10 per month to maintain a garden (…) I am not trying to say that individuals in East Baltimore are less educated, or less apt, or less organized, but would need to respect completing basic demands that your income might not be able to stretch to. And you don't want to keep the monetary contribution to maintain your own environment. It is still important, but in the list of important things I much prefer to take it and buy food" (KI 7 M-EE).

Discussion

The themes of "Boarded Houses," "High Speed. That's a Problem," "A lot of Crime," and "It has a calm to It," fit within existing theories of passive and active engagement (Berman et al., 2008; Kuo & Sullivan, 2010) and societal and community level factors of resilience (Szanton & Gill, 2010. The "Community builder" theme fits within theories of creating and sharing spaces (Sullivan et al., 2004). Themes of "You do know when people don't care about you" and "Maintained" fit within the historical segregation and disinvestment in Baltimore City (Gomez, 2012) and the United States as well as theories about social capital (Pretty & Ward, 2001).

Potential benefits of green spaces from passive engagement are in competition with those space promoting active engagement. Potential and experienced threats, including those within our study, including reported sexual violence (41%) are twice the rate those reported elsewhere (14-22%) (Smith, et al, 2010). Add on top of that a high prevalence of vacant property, traffic, and crime contribute to a heavy burden from environments that actively engage. Vacant property attracts "rats and trash", and serve as a constant reminder of neighbors who have lost their homes. Baltimore is in the 90th percentiles of the country for "High Speed. That's a Problem," as 1,226 pedestrian were hit by cars in 2016, and 17 died (Maryland Department of Transportation, 2017). Violent crime rates are seven times the national average and are responsible for psychological and physical injuries, as well as 343 homicides in 2017 (Rector, 2017). All of these threats exist where people live and cue individuals into a built and social environment that causes stress. Green spaces may offer the opportunity for passive engagement of non-threatening stimuli, facilitating decreased mental fatigue (Berman et al., 2008; Kuo & Sullivan, 2001) and adding "calm."

Creation of green space by community members out of vacant lots creates space for people to come together and build community. The negative correlation in this study between greenness and crime (β =-0.246, $p<.01$) supports the hypothesis that greener communities are safer (Sullivan et al, 2004). Similar to what has been described in the literature (Dulin-Keita, Casazza, Fernandez, Goran, & Gower, 2012; Jesdale, Morello-Frosch, & Cushing, 2013; Pratt, Vadali, Kvale, & Ellickson, 2015), we found inequity in environments, including levels of greenness, traffic proximity, vacant property, crime, violence, income and education. These inequities may be the result of neglect (Power, 1983), historical power imbalance (Gomez, 2012) and the ability of communities to leverage influence over their environment (Pretty & Ward, 2001).

At a population level we found a non-significant association of greenness with log transformed cortisol (β =9.3, p=.097), DHEA (β=.71, p=.61) and the ratio of cortisol to DHEA (β= 4.7, SE=4.1 p=.255, 95% CI [-3.4, 12.8]). What is not captured in these findings is the quality of the green spaces, how well they are maintained, and how accessible they are to vulnerable populations. When maintained by the city or the community, green spaces were described as "community builders," and the spaces have "a calm to it," similar to findings in literature (Sullivan et al., 2004).

There was no significant difference in cortisol levels among those who reported sexual violence (M=12.47, 95% CI [3.3, 21.9]) than those who did not (M=13.66, 95% CI [2.88, 24.44]) as both groups were likely to be highly stressed.

NDVI scores among participants ranged from 0.041 to 0.217, where some might have a garden or park on their block others have to walk "A mile" through neighborhoods with "High Speed" (β=-0.011, p<.01), "A lot of Crime" (β =-0.246, p<.01), and "Boarded house[s]" (β=-0.19, p<.01). These barriers to green space determine how much community members are able to enjoy the potential benefits (de Vries et al., 2013).

Our findings suggest the importance of nurturing existing green space, especially in neighborhoods living with systematic institutional oppression, segregation, and disinvestment resulting in communities who struggle to leverage influence over their environment (Pretty & Ward, 2001). We found significant ($p<.05$) economic differences between those who reported sexual violence (88%) and those who did not (68%), for individual income less than $30,000 (200% of the Federal Poverty Level). Furthermore there were significant differences between the number of unprotected sex partners for those reporting sexual violence (mean=3.9, 95% CI [2.31, 5.63]) and those who did not (mean=2.45, 95% CI [2.1, 2.8]). When looking at unprotected sex partners, those individuals living below 200% of the federal poverty level reported sexual violence (mean=4.1, 95% CI [2.28, 6.1]) and had 1.7 more partners ($p=.068$) than those who did not (mean=2.46, 95% CI [2, 2.9]). While this does not show causality, it does speak to the potential of income as a factor in negotiating sex and safe sex practices.

A meta-synthesis of studies looking at direct impacts on air quality, carbon reduction, water regulation, shading, and aesthetics found that for every dollar spent on planting, maintaining, irrigation, removal, and administration, the city gained 18 cents in net benefits (Song, Tan, Edwards, & Richards, 2018). That is a net benefit of $968,760 from the urban forest budget alone in Baltimore City. What is not included in these estimates are indirect benefits (i.e., health care, crime rates), quality of life, and as the cost benefits of addressing these inequities.

Limitations and Strengths

The non-probabilistic sample for the quantitative salivary and survey data included self-identified Black or African American women between the ages of 18-44 recruited at a sexually transmitted infection clinic in Baltimore City, MD. Not only are the results not generalizable but the nature of the sampling introduces selection bias since all of the sample are more likely to have experienced sexual abuse and other traumatic events than women living in other communities. Also the clinics are free to the citizens of Baltimore and are located in poor neighborhoods that are almost entirely African American due to the historical patterns of segregation and lack of investment described above. To our knowledge, the measurement of cortisol and DHEA at waking has only been studied once before (Prall & Muehlenbein, 2015). Prall & Muehlenbein tested healthy "college-aged" males (n=20) and females (n=18) recruited from a primarily residential Midwestern university in a midsized "college town" (2015). Compared to the findings in our study, the males in Prall & Muehlenbein had lower levels of cortisol (mean=11.12, SD=5.3), higher levels of DHEA (mean=.61, SD=.64) and a higher ratio than ours at 18:1. When comparing women in our study to those in Prall & Muehlenbein study, levels of cortisol (mean=12, SD=4.9) and DHEA (mean=0.36, SD=.297) were both lower and the ratio was even larger at 33:1 (2015) in this presumably low stressed sample. Additional studies looking at the ratio of cortisol to DHEA have been in morning (0800-0900) among older men (van Nieker, Huppert, & Herbert, 2001), blood serum baseline among young adults (Jin et al., 2016), and the majority as part of stress tests (Izawa et al., 2008, Jiang et al., 2017; Lam, Sheilds, Traineor, Slavich, & Yonelinas, 2018). Therefore the findings related to greenness and an increase in the ratio of cortisol to DHEA must be interpreted with caution given only one other known study among a group of healthy college-aged participants at waking with a ratio that was higher and all the others studies not collected at waking with a lower ratio than ours as well as the still developing science of the meaning of biomarkers representing the complex physiological stress response..

Another major limitation was the selection of factors controlled for in the multilevel modeling analysis. There is the issue of over controlling in analysis as well as not being able to see and understand the effect of any of the factors controlled for in the outcome.

The key informants (n=7) were not a part of the quantitative analysis and the three who were, were not systematically sampled. Other quantitative participants may have had very different descriptions of green space, including the unexposed. Furthermore, the quantitative (n=98) and qualitative (n=10) samples sizes were very different, thereby this study is heavy on the quantitative and light on qualitative. The lack of a cohesive audit trail for this study, a sole interviewer and coder with a bias towards the value of greens spaces, are a threat to the validity and reliability of the findings.

Strengths for this study encompass the rigor of this study's findings, including truth value, applicability, consistency, and neutrality (Lincoln & Guba, 1985). The multiple sources of data and multiple kinds of data analyzed, including the historical records, interviews, remote sensing, and surveys, increased the depth of understanding of the context of the quantitative findings and all supported the results of the quantitative data analysis. At the same time there are limited roadmaps for rigorous combining and integrating these multiple types of data. These findings focus on people living in Baltimore City, who are vulnerable for a multitude of reasons, and, while their experience is unique, there is a singular connection through the shared ecosystem of the planet.

Conclusions

The intersection of humans and their environment is central to the health of individuals, families and communities. Positive associations between Greenness and physiological-resilience operationalized as the ratio of cortisol to DHEA align with feelings of calmness and community. Inequitable distribution, access, and maintenance to green spaces speak to the influence of vulnerable groups within their environment. The environments where people live, work and play vary across social stratum. In many instances, space is limited both inside and outside people's houses, and there needs to be more shared communal spaces where people can gather. Mitigation of the causes of abnormally warm temperatures (plant CO2 sequestration) (National Research Council, 2015) and adaptation of urban environments to lessen the heat island effect (i.e., shade and tree transpiration) (Livesley et al., 2016) are central to building resilience of individuals and community to the increasing impact of climate change, including potential aggression and violence (National Center for Environmental Health, 2015; Levene & Conversi, 2014). Interventions are needed to promote the resilience of natural urban ecosystems that support individual and community bio-psychosocial health against extreme stress or shocks that would otherwise compromise health and wellbeing (Petros, Opacka-Juffry, & Huber, 2013; Szanton & Gill, 2010) and the planet that supports our health and our civilization (Whitmee et al., 2015).

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Table 8
Diversity Index and percent Black or African American

Diversity Index/ Percent African American	Baltimore City	Penn North-Reservoir Hill	Madison-East End	Roland Park-Poplar Hill	Charles Village-Barclay
2010	54.5 / 63.8%	19.3 / 90.3%	23.2 / 90.3%	38.9 / 7.9%	67.8 / 34.7%
2016	55.5 / 62.4%	30.6 / 84.9%	30.4 / 88.1%	36.7 / 6.8%	68.0 / 33.7

Table 9
Vacant Properties by Community Statistical Area, years 2013-2016

Vacant properties	2013	2014	2015	2016
Baltimore	8.0%	8.1%	8.2%	8.0%
Penn North-Reservoir Hill CSA	16.3%	15.8%	16.4%	15.4%
Madison-East End CSA	20.7%	20.1%	19.9%	18.4
Roland Park-Poplar Hill CSA	0%	0.1	0.1	0%
Charles Village-Barclay CSA	6.8%	5.7	5.4	7.4%

Table 10
Demolition permits per 1000 residents, years 2013-2016

	2013	2014	2015	2016
Penn North-Reservoir Hill CSA	1.9	2.1	3.8	2.4
Madison-East End CSA	3	2.3	4.4	2.8
M-EE CSA	4.6	15.8	4.0	7.7

Table 11
Permits for Rehabilitation of Buildings

	2013	**2014**	**2015**	**2016**
Penn North-Reservoir Hill CSA	4.2%	2.0%	4.1%	2.1%
Madison-East End CSA	1.8%	1.2%	2.7%	2.0%

Table 12
Crime/violent crime per 1000 Residents

	U.S.	Baltimore	Penn North-Reservoir Hill	Madison-East End	Roland Park-Poplar Hill	Charles Village-Barclay
2010	33.5 / 4.1	61.4 / 15	64.2 /18.8	65.5 / 25.1	32.1 / 2	74.3 / 1 7.1
2016	28.4 / 3.86	63 / 17.6	66.7 / 15.3	86.7 / 27.6	27.1/4.1	72 / 20.9

Table 13
Greenness and Square Feet of Land per Person

	Baltimore	Penn North-Reservoir Hill	Madison-East End	Roland Park-Poplar Hill	Charles Village-Barclay	Quantitative Sample
Greenness	0.0041-0.22	0.17	0.073	0.18	0.1	0.114
Ft^2 of land/ person	357	4238	1101	8,351	1,695	Not Available

Table 14
Demographic Data, 2016

	US	Baltimore	Penn North-Reservoir Hill	Penn North-Reservoir Hill	Roland Park-Poplar Hill	Charles Village-Barclay
High School or Greater	87%	78.4%	74.1%	71.6%	88%	78.6
Below FPL	15.1%	18.3%	29.4%	32.4%	3.6%	25.9%
Median Income	$55,322	$44, 262	$34,346	$29,439	$107,925	$34.620

Table 15
Select Baltimore City Budgets in millions of dollars

	Park Maintenance	Urban forestry	Horticulture	Right of way Landscape Management	Traffic Safety	Police Patrol
2018	$12.909	$5.581	$1.904	$4.096	$9.477	$259.3
2019	$12.986	$5.382	$1.814	$3.782	$8.756	$277.6

Figure 15

Greenness and HOLC Grades by CSA

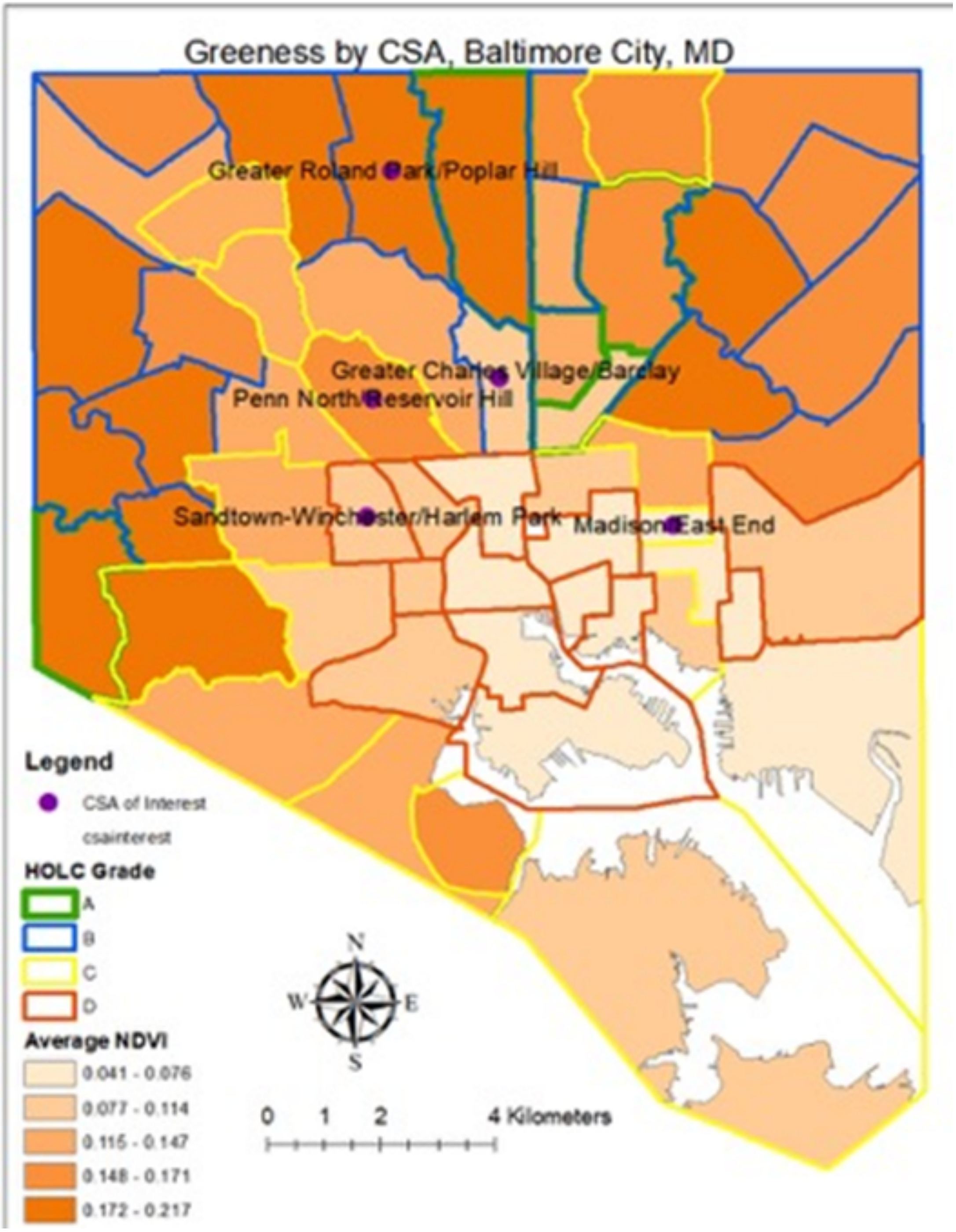


Figure 16
Overview of Community Statistical areas

Figure 17
Vacant Property by Community Statistical Area

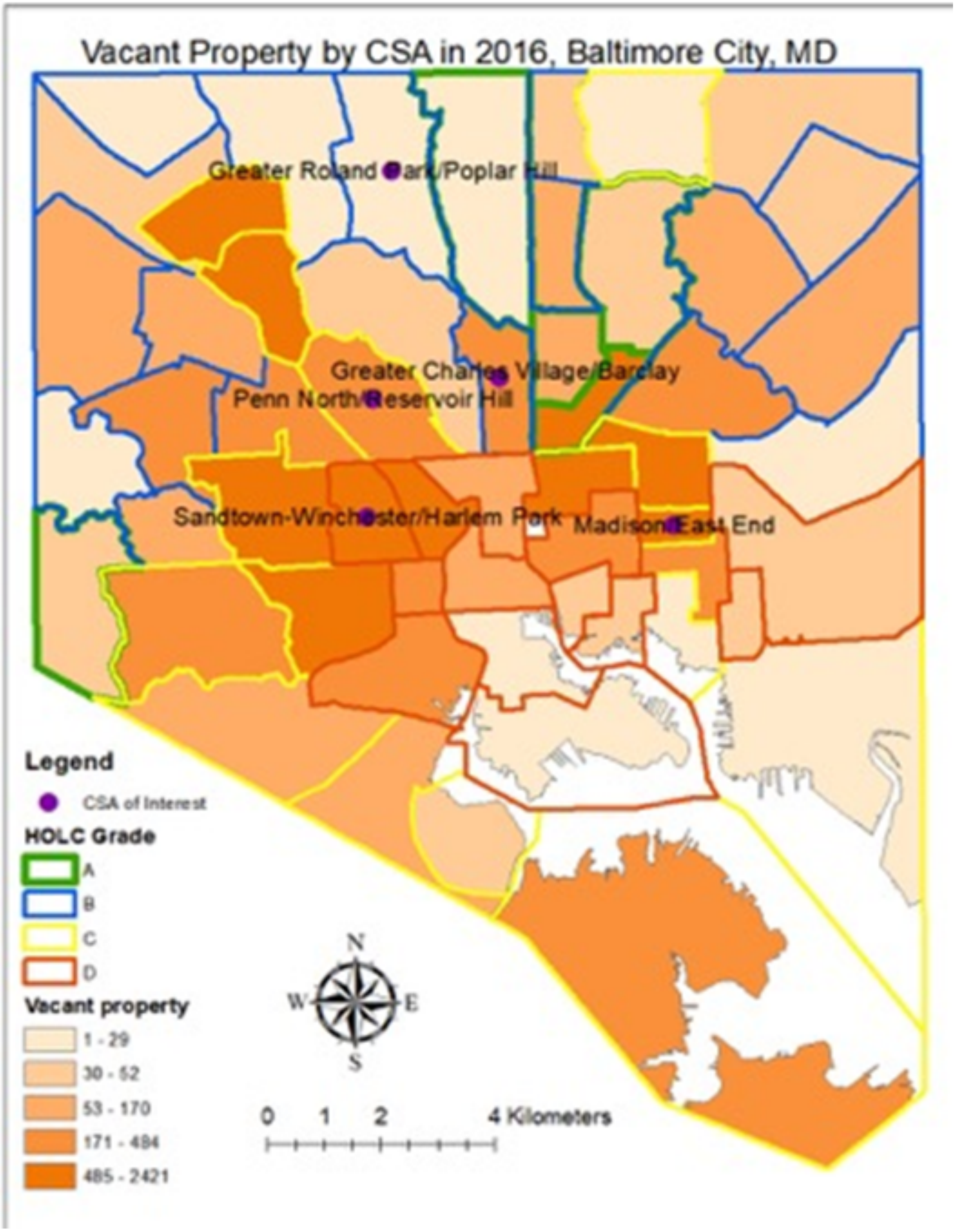


Figure 18
Traffic Proximity by Community Statistical Area

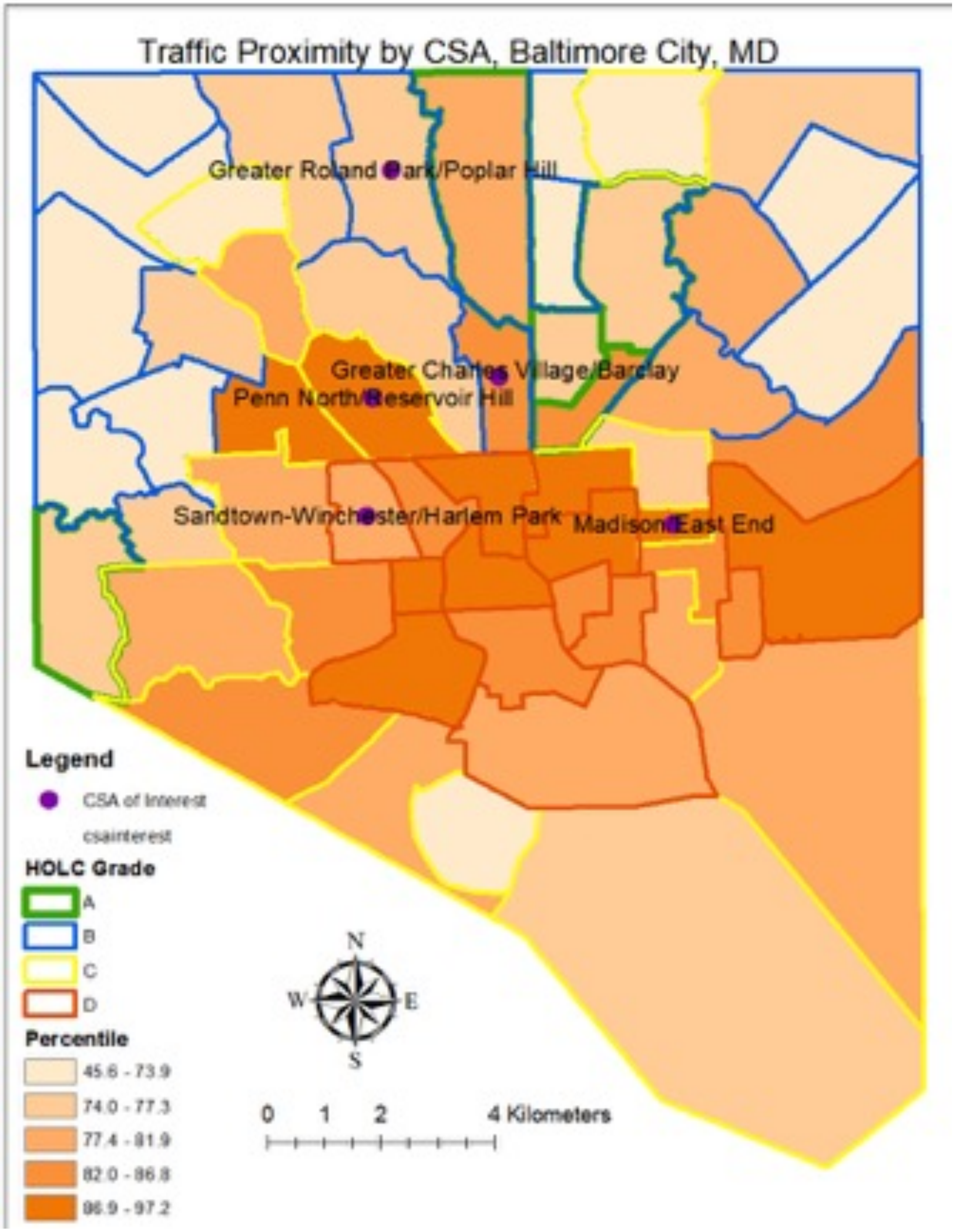
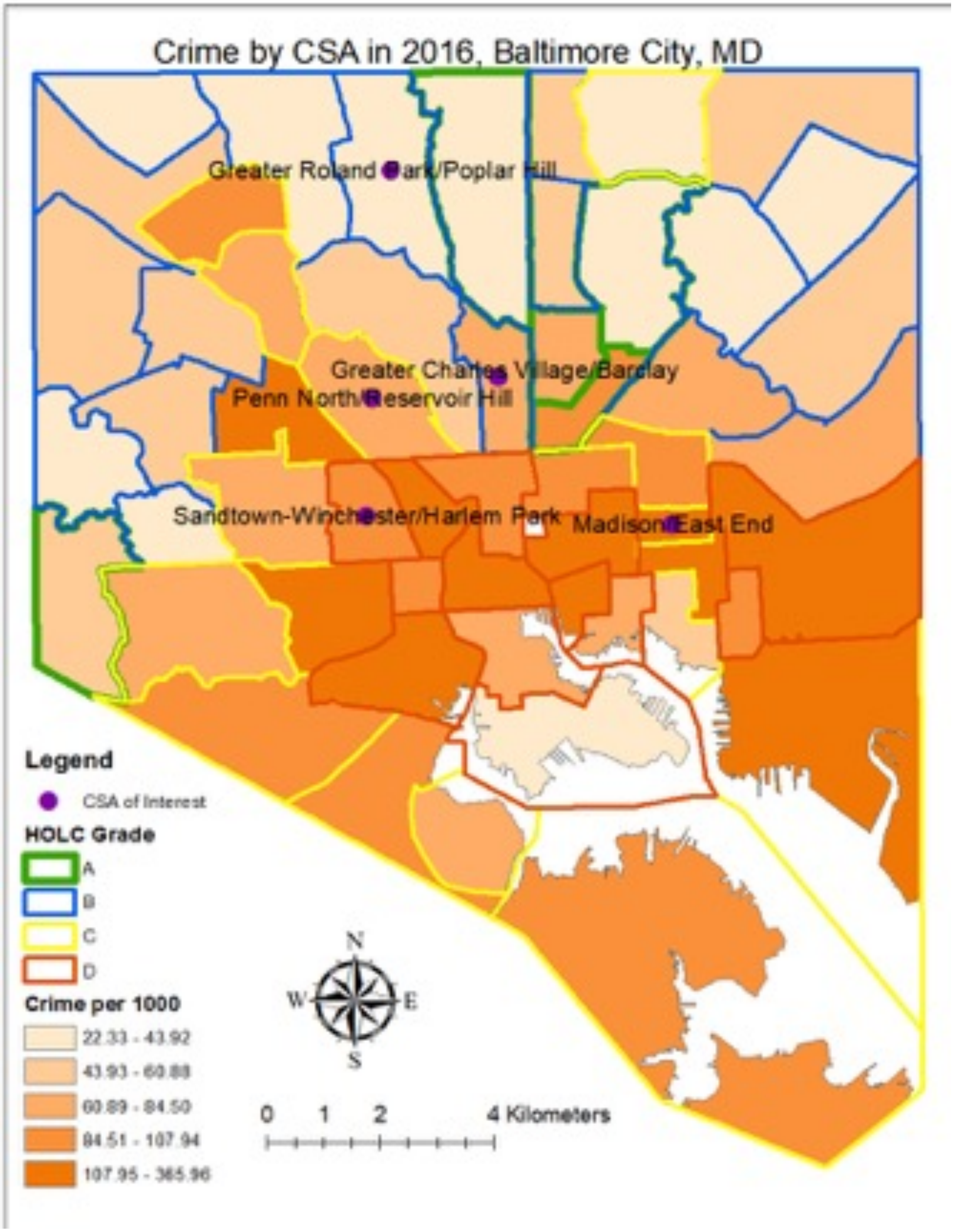


Figure 19
Crime by Community Statistical Area



CHAPTER FIVE: DISCUSSION

Introduction

The purpose of this dissertation was to examine the relationship between of greenness and physiological-resilience among African American women, ages 18-44 in Baltimore, Maryland. This study was framed within an adaptation of Szanton and Gill's *Society-to Cells Resilience Model* (2010) and provides health professionals, policy makers, and, most importantly, communities with preliminary evidence of the potential associations of greenness and physiological-resilience. This dissertation explored greenness physiological-resilience among African American women in Baltimore, Maryland, in the United States. Physiological-resilience is the capability of biological processes in shielding cells, tissues, and organs from stress and in supporting healthy functioning (Karmin & Kertes, 2017; Szanton & Gill, 2010). This dissertation considered the relationship between greenness and resilience within the "Society" level (i.e., safety in environment, and educational, and career opportunities) and "Community" level (i.e., built environment). As part of the "society" level, we operationalized "safety in the environment" as experience of sexual violence, crime, unprotected sex, and perceived stress. "Education and career opportunities" were operationalized as individual income and education. On the "community" level, traffic proximity and vacant properties were operationalized as the "built environment."

Quantitative data came from parent study salivary samples and surveys (NIH R01HD077891, PI: Jamila Stockman) asking about sexual violence, individual income, education, unprotected sex, and perceived stress. Salivary biological markers (cortisol and DHEA), public records (crime, vacant properties and traffic proximity), and remote sensing of chlorophyll (greenness) from satellites, a validated measure called normalized difference vegetation index (NDVI) (Rhew et al, 2011), were also quantitative data sources (see Table 16). Additionally, to contextualize the quantitative findings, data from multiple sources was used: 1) aerial and ground level images for specific areas of the city were analyzed in combination with 2) in depth qualitative interviews of purposively sampled key informants (KI) and "exposed" informants (EI), 3) field notes, and 4) historical records of Baltimore. "Exposed" informants (n=3) were primary study participants who reported sexual violence and lived in neighborhoods within community statistical areas from the highest quintile (NDVI scores between 0.15 to 0.21) and lowest quintile (NDVI scores between 0.043 to 0.078). Key informants (n=7) were purposively sampled from the same community statistical areas (CSA) including Penn North-Reservoir Hill (highest quintile) and Madison-East End (lowest quintile). The exposed informants all reported sexual trauma including adult forced sex, gang rape, adult stranger rape, and partner sexual abuse. The exposed informants were between ages of 20-30, similar to the study as a whole (mean=26.7, 95% CI [25-28]). The median number of sex partners was two, and partner risk behaviors were 1 (max=4). The median numbers of crime within 100 meters was 22, and traffic proximity and vacant properties were both in the highest quintiles. Key informants included young (n=4) and middle-aged adults (n=3). Key informants were not asked about sexual violence, and none disclosed any experience of sexual violence. However, in the United States over thirty percent of women report physical violence by an intimate partner, including sexual violence (Smith et al., 2010), so there is the potential that at least two of the Key Informants experienced violence from a partner.

This chapter presents a summary of the results of the study in the framework of the two study aims. Findings will be discussed for each individual aim, followed by the strengths and limitations of the study. Finally, the implications of this study will be described, and suggestions for future research will be discussed.

Specific Aims

The specific aims of this dissertation were:

Aim 1: Examine the relationship of neighborhood greenness (operationalized as normalized difference vegetation index) and physiological-resilience (operationalized as ratio of cortisol to DHEA) among urban-dwelling African American women who are at high risk of HIV.

The hypothesis for the first aim is that urban-dwelling African American women living in neighborhoods with higher levels of greenness will have a higher ratio of cortisol to DHEA at waking.

Aim 2: Understand the resilient potential of urban-dwelling African American women living with different levels of greenness.

Summary of Findings by Aims

Aim 1

Aim 1 examined the relationship of neighborhood greenness (NDVI) and physiological-resilience (ratio of cortisol to DHEA) among urban-dwelling African American women who are at high risk of HIV after controlling for factors of resilience including society level (safety in environment, educational & career opportunities) and community level (built environment).

Analysis of geospatial data from 98 African American women was conducted using Landsat satellite remote sensing of near infrared (NIR) and visible red light (RED) (NDVI= [NIR-RED)/[NIR+RED]). Greenness (NDVI) ranged from 0.044 to 0.214 (mean=0.11, SD=0.039) at 100-meter buffers (about the size of a typical city block) around participant's homes. The ESSENCE Research Team also analyzed salivary biomarkers: cortisol, ranging from 1.3795 to 312.843 nmol/L (mean=13.162, SD=36.36), and dehydroepiandrosterone (DHEA), ranging from 0.305 to 6.874 nmol/L (mean=2.446, SD=1.41). The ratio of the two biomarkers ranged from 1.9 to 190 (mean=11.87, SD=22.43, 95% CI [7.38, 16.37]).

We analyzed data with univariate analysis by looking at the means, medians, standard deviations, skewness, kurtosis, histograms, frequencies, stem and leaf plot, and scatter plots (see Figures 5-12). After initial exploratory analysis including bivariate associations, multivariate regression analysis and confirmatory factor analysis of psychometric measures, we built a multilevel generalized linear regression analysis of greenness and physiological resilience incorporating community and societal factors.

The ratio of cortisol to DHEA was calculated using the two-day averages of each biomarker at waking. The biomarkers were averaged across the two days of cortisol (mean=0.48, [2.1,7.4]) and DHEA (mean=414.0, [366.1, 461.9]. The mean of cortisol (mean in ug/dl * 27.59=13.2nmol/l) and DHEA (mean in pg/ml *0.0028=1.2nmol/l) were transformed into nanomoles per liter (nmol/L) to facilitate comparisons with the literature (Petros et al., 2013) and for calculating their ratio. Then we divided cortisol by DHEA to create a value representing the ratio (M=11.9, SD=22.4) of the two values (Cortisol/DHEA) (see Table 5) and our defined measure of resilience. Post-hoc analysis included calculation of the rise in cortisol from waking (M=13.3, SD=36.4) and at thirty minutes (M=10.5, SD=5.1) and the difference in the two as a measure of the rise (M=2.45, SD=4.4).

Due to the non-normal distribution, including positive skewness of the biomarkers and the ratio of cortisol to DHEA, we analyzed nine different transformations (see Figure 7). We explored the relationship of greenness with inverse square root transformation of the ratio of cortisol to DHEA as it came closest to the approximation of normality. A locally weighted scatterplot smoothing (LOESS) line of the relationship between greenness and the inverse square root of the ratio of cortisol to DHEA suggested a curvilinear relationship (see Figure 20). The interpretation of the inverse square root was not intuitive. The scatter plot of greenness with log-transformed ratio of cortisol to DHEA, the next closest transformation with a loess line approximated a positive linear relationship (See Figure 10). Due to a positive skew of the ratio of cortisol to DHEA, a Gamma (Family) distribution in the model was used (Manning & Mullahy, 2001). A generalized linear model (GLM) of the association of greenness (NDVI) with physiological-resilience (ratio of cortisol to DHEA) with Gamma (Family) distribution and logarithmic (log) transformation was built. The null model (see Table 17) of the association between greenness and resilience (cortisol/DHEA) while positive was not significant (β=4.72, p=0.26). To account for spatially correlated data, for the rest of the analysis we used clustered robust standard errors, though the null model was still not statistically significant in its association of greenness with physiological-resilience (operationalized as the ratio of cortisol to DHEA (β=5.54, p=0.26).

Aim two from the preliminary oral exam proposed testing hypothesized indirect effects of third variables (crime, violence) theoretically guided by associations of reduced crime and violence with higher levels of greenness (Kuo & Sullvian, 2001). This was with the understanding that the cross-sectional data eliminated temporal precedence (MacKinnon, Krull, & Chondra, 2000). The non-significant positive association between greenness and resilience violated the first requirement of mediation (Baron &Kenny, 1986). Taking this into account, the following three steps were tested. Crime (adjusted for population), was positively associated with greenness (β=-0.25, p<.01) meeting the second rule. Crime, however was not significantly associated with resilience (β=-0.24, p=.98), failing to meet the third requirement. When crime was added to the model of greenness and resilience (See Figure 21), the strength of the relationship increased (β =6.24, p=.26); however, it was not significant, violating the fourth requirement. The increase in the strength of the association of greenness and resilience suggests there may be effects from measured or unmeasured variables masking the association including mediation, confounding or by chance (MacKinnon et al., 2000).

The same steps were used to analyze mediation by sexual violence as a binary variable (β=-6.8, p=.22), and a categorical variable of exposure to sexual abuse (none, adult only, adult + childhood). The association of greenness was non-significant with the categorical variable of sexual violence exposure including adult only (β=-0.9, p=.91) and adult plus childhood (β=-8.5, p=.13). The relationship between sexual violence and resilience (cortisol/DHEA) was also non-significant: 1) Sexual Violence (β=0.049, p=.9), 2) categorical adult only (β= -0.11, p=.8), and 3) adult plus childhood (β= 0.08, p=.8). Again, all four requirements for mediation were violated. However, when running this model with sexual violence, the strength of the relationship between greenness and physiological-resilience (operationalized as the ratio of cortisol to DHEA) became slightly stronger (β = 5.5, p=.26).

The non-significant increase in the strength of the relationship between greenness and physiological-resilience (operationalized as the ratio of cortisol to DHEA) by the inclusion of crime and again with sexual violence raised the question whether it was just chance or was there some other reason. Covariates chosen *a priori* were added one at a time to the model to facilitate explanation in the error in the association between NDVI and the ratio of cortisol to DHEA. Vacant properties, traffic proximity, education, income, crime, sexual violence, perceived stress, and unprotected sex were all included in the model.

Greenness was non-significant (β =7.5, SE=4.9, p=.124, 95% CI [-2, 17]) in the full adjusted model; however, when we clustered with community statistical areas (CSA) (n=55), we found one standard deviation (0.039) increase in greenness associated with a 34 % increase (β = 7.5, SE=3.39 p=.026, 95% CI [.89, 14.2]) in physiological-resilience (operationalized as the ratio of cortisol to DHEA). In other words, increased greenness was associated with increased capability to respond to physiologically-anticipated waking stress adjusting for the community and societal level factors. The final variance inflation factor to test for collinearity was acceptable (mean=2.11) (Belsley, Kuh, & Welsch, 2005).

The significant negative associations of greenness at 100-meters with population adjusted crime (β=-0.246, p<.01) was also found with population adjusted traffic proximity (β=-0.011, p<.01) and vacant properties adjusted for population (β=-0.19, p<.01). In other words, the more greenness there was, the less crime, less traffic, and fewer vacant properties there was. The negative relationship between crime and green space in this study supports findings elsewhere (Bogar & Beyer, 2016; Garvin, Carnnuscio, Branas, 2013). As far as we know, there has been no direct analysis describing the negative relationship we found between greenness and traffic density or vacant properties. There has been a study that observed differences in health outcomes based on presence of greenness and traffic (noise and air pollution) including the prevalence of low birthweights (Hystad et al., 2014). Age had a small but significant negative association with greenness (β=-0.001, $p<.05$), suggesting in our sample that the higher in age someone is, the less greenness on their block. To our knowledge there is has been no study exploring this relationship.

Analysis of the relationship between greenness and ratio of cortisol to DHEA controlling for other factors of resilience revealed that the relationship between greenness and physiological-resilience is a multi-factorial. Sixty-eight percent of the participants in this study have an individual income of less than 200% of the federal poverty level (n=67), 60% have less than $10,000 annually, and 81% have obtained high school education equivalency or higher.

Seventy-eight percent (n=32) of the women in the quantitative analysis who reported sexual violence sexual (n=41) also reported sexual violence as children. Neighborhoods where participants live have rates of crime 4-12 times higher than the national average (Federal Bureau of Investigation, 2017). In terms of community level or built environment, traffic proximity was in the 70-90th percentile of the nation, and vacant property rates 2-3 times higher than the Baltimore city average. Even with all of these stressors, the physiology of this vulnerable group still strives to maintain resilience, anticipating stress, and responding in a resilient manner.

Post-hoc analysis comparing women exposed (n=41) and unexposed (n=58) to sexual violence revealed non-significant differences in cortisol (difference=1.18, p=0.87), DHEA (difference=0.4897, p=0.49), and the ratio of cortisol to DHEA (difference=-0.28, p=0.9). Experience of sexual violence exposure as a child and adult to sexual violence as a categorical variable (unexposed, exposed as adult, exposed as adult and child) in bivariate analysis of cortisol, DHEA, and the ratio of cortisol were all non-significant (see Table 18). We did see trends in the comparison of these categorical groups in linear predictions clustered at the community statistical area (see Figure 22). We hypothesize that the non-significance stems from our inability to account for the frequency and ages of the experience of sexual violence for which participants were exposed to over their lifetime (Sunderman, Chu, & DePrince, 2013). There were non-significant differences in greenness (difference=0.01, p=0.2) between women exposed and unexposed to sexual violence. While this finding has not explicitly described in the literature, greenness has been negatively associated with income (Kihal-Talantikite et al., 2013) and positively associated with residential segregation (Jesdale et al., 2013).

The non-significant but positive association between the greenness of where people lived with cortisol (β = 9.3, p=.097), DHEA (β = .71, p<.61) and the ratio of cortisol to DHEA (β = 4.7, p<.33) were in the direction and strength expected. This sample of women was highly stressed related to their low income, lack of employment, living in neighborhoods characterized by crime and vacant houses, and relationship characteristics putting them a risk for HIV whether or not they had also experienced sexual abuse. As a group they had average waking cortisol (mean=13.2, SD36.4) higher than at 30 minutes (mean=10.5, SD=5.1) similar to other stressed groups (see Figure 13) (Barksdale, Woods-Giscombe, & Logan, 2011; Pinto, Correia-Santos, Cost-Leite, Levendosky & Jongenlen, 2016). Slightly higher levels of cortisol and significantly higher DHEA levels in this study (cortisol=13.6nmol/L, [5.8, 20.5], DHEA=1.15 (95%CI [1.03, 1.29) compared to those in Prall and Muehlenbeing study (cortisol=12nmol/L SD=4.94, DHEA=0.35, SD=0.25) (2015), suggests anticipation of stress and compensatory action (Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2012). The elevated levels of cortisol and DHEA and the ratio are part of the complex system working to maintain optimal capability to respond to physiologically anticipated waking stress (Izawa et al., 2009). The non-significant positive association between greenness and the ratio of cortisol to DHEA even among those who reported sexual violence (see Figure 14) reflect the stress phase of the response (Prall, Larson & Muehlenbeing, 2017), where DHEA peaks first as cortisol is still rising (Izawa et al., 2009). When looking at a linear prediction of greenness with waking cortisol, cortisol rise, and the ratio of cortisol to DHEA were mixed (see Figure 22). What we are unable to see is due to sampling at one time point for DHEA and lacking data on its sulfate (DHEA-S) is the expected plateauing of DHEA in response to the stress of waking (Izawa et al., 2008).

To our knowledge, the measurement of cortisol and DHEA at waking has only been studied once before (Prall & Muehlenbein, 2015). Additional studies looking at the ratio of cortisol to DHEA in salivary samples have been in the morning (0800-0900) among older men (van Nieker, Huppert, & Herbert, 2001) and the majority as part of stress tests (Iwaza et al., 2008, Jiang et al., 2017; Lam, Sheilds, Traineor, Slavich, &

Yonelinas, 2018). Therefore the findings related to greenness and an increase in the ratio of cortisol to DHEA must be interpreted with caution given only one other known study among a presumably low stressed college-aged sample at waking with a ratio that was higher, and all the others studies collected at times other than waking with lower ratios than ours.

Aim 2

Aim 2 explored the resilient potential of urban-dwelling African American women living with different levels of greenness.

Potential benefits of green spaces from passive engagement are in competition with active engagement of potential and experienced threats including in this study, reported sexual violence (41%) twice reported elsewhere (14-22%) (Smith, et al, 2010) and a high prevalence of vacant property, traffic, and crime. Vacant property attracts "rats and trash" and serves as a constant reminder of neighbors who have lost their homes. Baltimore is in the 90th percentiles of the country for traffic proximity. In in 2016, 226 pedestrians were hit by cars and 17 died (Maryland Department of Transportation, 2017). Violent crime rates are seven times the national average, with 343 homicides in 2017, and are responsible for psychological and physical injuries (Rector, 2017). All of these threats exist where people live and cue individuals into a built and social environment that causes stress. Green spaces may offer the opportunity for passive engagement of non-threatening stimuli, facilitating decreased mental fatigue (Berman et al., 2008; Kuo & Sullivan, 2001).

Creation of green space by community members out of vacant lots creates space for people to come together and build community. The negative correlation in this study between greenness and crime (β =-0.246, p<.01) supports the hypothesis that greener communities are safer (Sullivan et al, 2004). Similar to what has been described in the literature (Dulin-Keita, Casazza, Fernandez, Goran, & Gower, 2012; Jesdale, Morello-Frosch, & Cushing, 2013; Pratt, Vadali, Kvale, & Ellickson, 2015), we found inequity in environments, including levels of greenness, traffic proximity, vacant property, crime, violence, income and education. These inequities may be the result of neglect (Power, 1983), historical power imbalance (Gomez, 2012) and the ability of communities to leverage influence over their environment (Pretty & Ward, 2001).

We found a non-significant association of greenness with log transformed cortisol (β =9.3, p=.097), DHEA (β =.71, p=.61) and the ratio of cortisol to DHEA (β = 4.7, SE=4.1 p=.255, 95% CI [-3.4, 12.8]). What is not captured in these findings is the quality of the green spaces, how well they are maintained, and how accessible they are to vulnerable populations. When maintained by the city or the community, green spaces were described as "community builders" and spaces that have "a calm to it," similar to findings in literature (Sullivan et al., 2004).

NDVI scores among participants ranged from 0.041 to 0.217. Where some might have a garden or park on their block, others have to walk "A mile" through neighborhoods with "High Speed" (β =-0.011, p<.01), "A lot of Crime" (β =-0.246, p<.01), and "Boarded house" (β =-0.19, p<.01). These barriers to green spaces determine how much individuals are able to enjoy the potential benefits (de Vries et al., 2013).

Our findings suggest the importance of nurturing existing green spaces, especially in neighborhoods living with systematic institutional oppression, segregation, and disinvestment, resulting in communities who struggle to leverage influence over their environment (Pretty & Ward, 2001). We found significant ($p<.05$) economic differences between those who reported sexual violence (88%) and those who did not (68%), and for individual income less than $30,000 (200% of the Federal Poverty Level). Furthermore there were significant differences in the number of unprotected sex partners for those reporting sexual violence (mean=3.9, 95% CI [2.31, 5.63]) and those who did not (mean=2.45, 95% CI [2.1, 2.8]). When looking at unprotected sex partners, those living below 200% of the federal poverty level were more likely to report sexual violence (mean=4.1, 95% CI [2.28, 6.1]) and had 1.7 more partners ($p=.068$) than those who did not (mean=2.46, 95% CI [2, 2.9]). While this does not show causality, it does speak to the potential of income as a factor in negotiating sex and safe sex practices.

Investment in green space by cities, communities, and institutions pays back in multiple ways and is influenced by institutional discrimination through the historical grading of neighborhoods as “declining” and “hazardous” (Zenou & Boccard, 2000). A meta synthesis of studies looking at direct impacts on air quality, carbon reduction, water regulation, shading, and aesthetics found that for every dollar spent on planting, maintaining, irrigation, removal, and administration, the city gained 18 cents (Song, Tan, Edwards, & Richards, 2018). That accounts for a net benefit of almost a million dollars from the urban forest budget alone in Baltimore City. What is not included in those estimates are indirect benefits (i.e., health care and crime reduction) and the effect on quality of life.

Limitations and Strengths

The non-probabilistic sample for the quantitative salivary and survey data included self-identified Black or African American women between the ages of 18-44 recruited at a sexually transmitted infection clinic in Baltimore City, MD. Not only are the results not generalizable but the nature of the sampling introduces selection bias since all of the sample are more likely to have experienced sexual abuse and other traumatic events compared to women living in other communities. In addition, the clinics are free to the citizens of Baltimore and are located in poor neighborhoods that are almost entirely African American due to the historical patterns of segregation and lack of investment.

Another major limitation was the selection of factors controlled for in the multilevel modeling analysis. There is the issue of over controlling in analysis as well as not being able to see and understand the effect of any of the factors controlled for in the outcome. The exploratory analyses of the regression model with the given sample size and predictors likely resulted estimation of empty cells. Different analysis could have included creation of a binary outcome of the ratio of cortisol to DHEA and run as a logistic regression.

The measure of greenness is an average measure within a 30-meter pixel measured from space. The 100-meter buffer used for this study is subject to influence from vapor in the air, pools, ponds, lakes, and rivers. While we excluded the largest body of water, the Patapsco River, we included other bodies of water, potentially underestimating the level of greenness of some participants. Furthermore, there is also no way to control for actual exposure to potential benefits of greenness if participants did not spend significant time outside. We were also unable to control for time at the address reported or if the address was invalid. There is also an issue of temporality as the NDVI was calculated with data from July 15, 2016, and we collected salivary samples over the years 2015 through 2018. The same questions of temporality exist in regard to crime (2016), vacant property (2016) and traffic proximity (2016).

Self-sample of salivary samples introduces a threat to test validity depending on the consistency of salivary samples being taken exactly at waking and at 30 minutes later. Furthermore, due to DHEA and cortisol samples coming from one time with the 24-hour diurnal variation, we are limited in our ability to predicted changes in both variables.

The key informants (n=7) were not a part of the quantitative analysis and the three who were, were not systematically sampled. Other quantitative participants may have had very different descriptions of green space, including the unexposed. Furthermore, the quantitative (n=98) and qualitative (n=10) samples sizes were very different, thereby this study is heavy on the quantitative and light on qualitative. The lack of a cohesive audit trail for this study, a sole interviewer and coder with a bias towards the value of greens spaces, are a threat to the validity and reliability of the findings.

In spite of the limitations, to our knowledge this study is the first to examine at the association of greenness using remote sensing with physiological-resilience operationalized as the ratio of cortisol to DHEA among African American women at high risk of HIV at waking. The study gave us a unique opportunity to explore physiological-resilience and greenness, with the reference data of a unique and vulnerable population. We have also found a potential effect size (.34) for future studies in estimating power calculations examining the relationship of greenness and physiological-resilience. We recommend collection of longitudinal DHEA and DHEA-S samples for any future studies.

Additional strengths for this study encompass the rigor of this study's findings, including truth value, applicability, consistency, and neutrality (Lincoln & Guba, 1985). The multiple sources of data and multiple kinds of data analyzed, including the historical records, interviews, remote sensing, and surveys, increased the depth of understanding of the context of the quantitative findings and all supported the results of the quantitative data analysis. At the same time there are limited roadmaps for rigorous combination and integration of the multiple types of data. These findings focus on people living in Baltimore City, who are vulnerable for a multitude of reasons, and, while their experience is unique, there is a singular connection through the shared ecosystem of the planet.

Implications for Theory

The mechanism of the relationship between green space and physiological-resilience are untested in this study. However, we found evidence that, among urban-dwelling residents, a sense of calm is identified in their experience of green space. Whether the calm from maintained green spaces comes from natural sights or sounds, cooler temperatures, or the space to gather and connect with people needs further exploration. The association we found between greenness and potential physiological biomarkers of resilience are suggestive of potential stress reduction including previously hypothesized decreases in mental fatigue, aggression, and potential parasympathetic activation.

The current study first gives support to the nursing theoretical framework, *Society-to Cells Resilience Model*, put forth by Szanton and Gill (2010), by demonstrating that indeed resilience can and is most completely conceptualized all the way from cells to societal levels. Our findings that physiological-resilience operationalized as the ratio of cortisol to DHEA was significantly associated with greenness is an important implication for further theory building in this framework. The findings of this dissertation support the natural ecosystem, represented here by greenness, in supporting resilience at a societal, community, and physiological level through potential passive engagement from natural sounds and sights, and the creation of spaces for social interaction with humans and other species (Berman, Jonides, & Kaplan, 2008; Irvine, Warber, Devine-Wright, Gaston, 2013; James, Hart, Banay, & Laden, 2016; Kuo, 2015, Sullivan et al., 2004; Szanton & Gill, 2010).

In a broader nursing sense, the natural ecosystem of urban, suburban, and rural areas exist within the larger context of the planet that supports the health and civilization of humans (Whitmee et al., 2015). Florence Nightingale highlighted the importance of the environment in nursing, and today it stands as one of our four pillars: Health, Environment, Human, and Nursing (Fawcett & Desanto-Madeya, 2013). Martha Rogers wove together the four pillars into the Science of Unitary Human Beings, the theory that humans and the environment are inseparable. Health and well-being are the expression of harmony between the human and the environment, with nursing facilitating the rhythms of life between and within (Fawcett & Desanto-Madeya, 2013).

The intersection of humans and their environment is central to the health of individuals, families, and communities (Demas & Carlgon, 2014). The environments where people live, work, and play vary across social stratum (Jesdale, Morello-Frosch, & Cushing, 2013). We found that, while space is limited, communities can come together to create shared communal spaces for people to gather. Trees, plants, and other vegetation provide ecosystem services, including mitigation of the urban heat island effect and sequestration of carbon dioxide (Founda & Santamouris, 2017), and from this study we learned, that green spaces facilitate people connecting with their community.

The relationship between greenness and physiological-resilience (operationalized as the ratio of cortisol to DHEA may be a part of a larger complex model of engagement (sympathetic vs parasympathetic activity) related to individuals and community's ability to influence their environment (social capital), neighborhood disorder (crime and vacant property) and sexual violence (cumulative and unprotected) (see Figure 23). Greenness is theorized to promote passive engagement (parasympathetic activity), whereas neighborhood disorder (crime and vacant property), sexual violence (cumulative and unprotected) may contribute to active engagement. Social capital may relate to an individual to negotiating sex and safe sex practices. Social capital may also relate to a community's ability to negotiate crime reduction and banking services that empowers rather than oppress. Social capital also may relate to the ability of communities to transform their community into one that promotes physiological-resilience..

Implications for Policy and Public Health Nursing

The distribution of green space in cities is a manifestation of historical and present day social and built environments. The findings of this study provide foundational data for the development of targeted health interventions to increase the modifiable factor of community greenness. The burgeoning area of science studying the impact of greenness on the resilience of African American women to stressors within the built and social environment will help guide interventions that benefit vulnerable populations, rather than exacerbating inequality or contributing to further marginalization and displacement through green-gentrification. This study moves the fields of nursing and environmental health beyond an earlier focus on immediate microbial and chemical environment exposure to include biopsychosocial implications of access to ecosystem services. Nursing is well positioned to address the promotion of community and individual resilience and support that paradigm. These findings provide policy makers, health professionals, and health systems a clear understanding of greenness as an instrument for the promotion of health of communities. Nursing professionals need to inform policy makers and health care systems of the importance of increased funding for maintenance of parks and urban forests as part of supporting the health of their constituency and communities. This study expands knowledge on the factors contributing to morbidity and mortality from violence of vulnerable populations, including African American women, who are already among the most vulnerable to environmental injustices.

The finding that one standard deviation (0.039) of greenness above the mean (0.11) was associated with increased physiological-resilience (operationalized as the ratio of cortisol to DHEA) among vulnerable groups living with inequitable social and built environmental stresses supports ongoing initiatives to increase the amount of green spaces in urban areas. Differences in greenness is something we can actually measure and compare.

The influence of greenness on physiological-resilience is not enough on its own and greening interventions should include litter abatement on sidewalks, urban forests, parks, and around street trees (National Center for Environmental Health, 2015).

Additionally, management efforts should be made to ensure green space access to all Baltimore City constituents. Interventions are needed to promote the resilience of natural urban ecosystems that support individual and community biopsychosocial health against extreme stress or shocks that would otherwise compromise well-being (Gunderson & Holling, 2002; Petros, Opacka-Juffry, & Huber, 2013; Szanton & Gill, 2010) and the planet that supports our health and our civilization (Whitmee et al., 2015).

The potential co-benefits of increased greenness in urban environments through decreased ground surface temperature (Napoli, Brandani, Petralli, & Orlandini, 2016), aggression (Younan et al., 2018), crime (Garvin, Cannuscio, & Branas, 2013), depression (South, Hohl, & Kondo, 2018), and the promotion of resilient physiology (Egorov et al., 2017) are life- and cost-saving. The findings of this study fit within existing literature regarding health outcomes of greenness (James et al, 2015; Kondo, Fluehr, McKeon, & Branas, 2018), and add evidence of those implications for governments, health systems, and individual healthcare providers. Mitigation of the causes of abnormally warm temperatures (plant CO2 sequestration) (National Research Council, 2015) and adaptation of urban environments to lessen the heat island effect (i.e., shade and tree transpiration) (Livesley, McPherson, & Calfapietra, 2016) are central to building the resilience potential of individuals and communities to the increasing impacts of climate change (National Center for Environmental Health, 2015).

Future research

This study benefitted from ongoing research with minimal additional burden on participants from vulnerable communities. Future research similarly would benefit from limiting impact when possible, while including and highlighting those who are already burdened with injustices in their local environments (Jesdale et al, 2013). Recommendations for future research include the collection of longitudinal data and testing the relationship of greenness with biological markers of resilience at waking and 30 minutes later. Furthermore, in addition to Cortisol and DHEA, the sulfate of DHEA (DHEA-S) should be included in analysis. The modeling of the biomarkers with greenness (NDVI) should be analyzed for the participant on the day when biomarkers are collected. Measures of crime would benefit from looking at time periods leading up to data collection, prior week, month, and quarter year. Measures of sexual violence would benefit from analysis of cumulative violence, including lifetime exposure to sexual violence and other violence. Experimental studies, natural or interventions are needed to better understand the mechanism of action and to test for differences in the resilience of vulnerable communities. Studies based on alternative model could start with looking heart rate variability and the ratio of cortisol to DHEA(S) among individuals and communities of different levels of social capital as they move through greenness and neighborhood disorder in space and time.

Conclusions

Since the dawn of the agricultural revolution, humans have been conducting a planetary experiment in the transformation of forests into fields, which increased exponentially with the dawn of the industrial revolution. The most vulnerable species, including the most vulnerable humans are already feeling the stress of global urbanization and deforestation. The health of all species, including humans and our civilizations are dependent on the resilience of the planet. Now is the time to participate in a global transformation with trees.

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Table 16
Measures Table

	Concept	Operationalized		Source	Type of data
Physiological Factors	**Physiological-Resilience (Hormonal Balance)**	Ratio of Cortisol to DHEA		ESSENCE	Continuous
Societal Factors	**Greenness (Natural Ecosystem)**	NDVI=(NIR-RED)/(NIR+RED)		NASA	Continuous
	Safety in the Environment	Sexual Violence	Adult	ESSENCE (n=98)	Categorical
			Adult+ Childhood		
		# of unprotected sex partners (12m)		ESSENCE (n=98)	Continuous
		Perceived Stress		ESSENCE (n=98)	Continuous
		Crime (100m)		City of Baltimore	Continuous
	Educational & Career Opportunities	High School or Equivalency		ESSENCE (n=98)	Binary
		Income: $30,000		ESSENCE	Binary
Community Factors	**Built Environment**	Traffic Proximity (% of country)		US EPA	Continuous
		Vacant Property (100m)		City of Baltimore	Continuous

Table 17
Full model

Physiological-Resilience		Unadjusted		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8		Model 9	
		Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue	Coef	pvalue
Greenness		4.72	0.26	4.72	0.33	5.50	0.26	5.73	0.24	6.70	0.14	5.97	0.12	4.95	0.14	6.98	0.04*	7.55	0.03*	7.55	0.03*
Sexual Violence	Adult	-0.11	0.88			0.01	0.97	-0.01	0.97	0.01	0.99	-0.06	0.82	-0.17	0.57	-0.21	0.41	-0.28	0.25	-0.27	0.27
	adult & child	0.09	0.83			0.24	0.46	0.19	0.60	0.31	0.38	0.25	0.46	0.32	0.34	0.34	0.31	0.37	0.29	0.38	0.29
unprotected sex		0.02	0.69					0.02	0.27	0.03	0.28	0.03	0.32	0.04	0.11	0.04	0.10	0.04	0.10	0.04	0.08*
Perceived Stress		-0.06	0.69							-0.07	0.66	-0.09	0.60	-0.12	0.46	-0.10	0.52	-0.11	0.50	-0.12	0.42
income		-0.30	0.49									-0.37	0.17	-0.04	0.87	-0.06	0.79	-0.10	0.65	-0.09	0.67
education		-0.44	0.24											-0.59	0.02*	-0.56	0.02*	-0.57	0.02*	-0.56	0.02*
crime		-0.24	0.98													8.76	0.16	7.06	0.26	6.11	0.43
vacant property		-0.21	0.98															4.77	0.19	4.55	0.16
traffic		0.00	0.99																	0.03	0.79

Table 18
Bivariate analysis of sexual violence exposure

	cortisol	DHEA	cortisol/DHEA
Adult only	β= -074, p=435	β= -0.37, p=0.75	β= -0.11, p=0.88
Adult and Childhood	β= 0.04, p=.951	β= -0.02, p=0.9	β= 0.08, p=0.83

Table 19
Select Baltimore City Budgets in millions of dollars

	Park Maintenance	Urban forestry	Horticulture	Right of way Landscape Management	Traffic Safety	Police Patrol
2018	$12.909	$5.581	$1.904	$4.096	$9.477	$259.3
2019	$12.986	$5.382	$1.814	$3.782	$8.756	$277.6

Figure 20

Scatter plot of Inverse Square Root of Resilience and Greenness with LOESS line

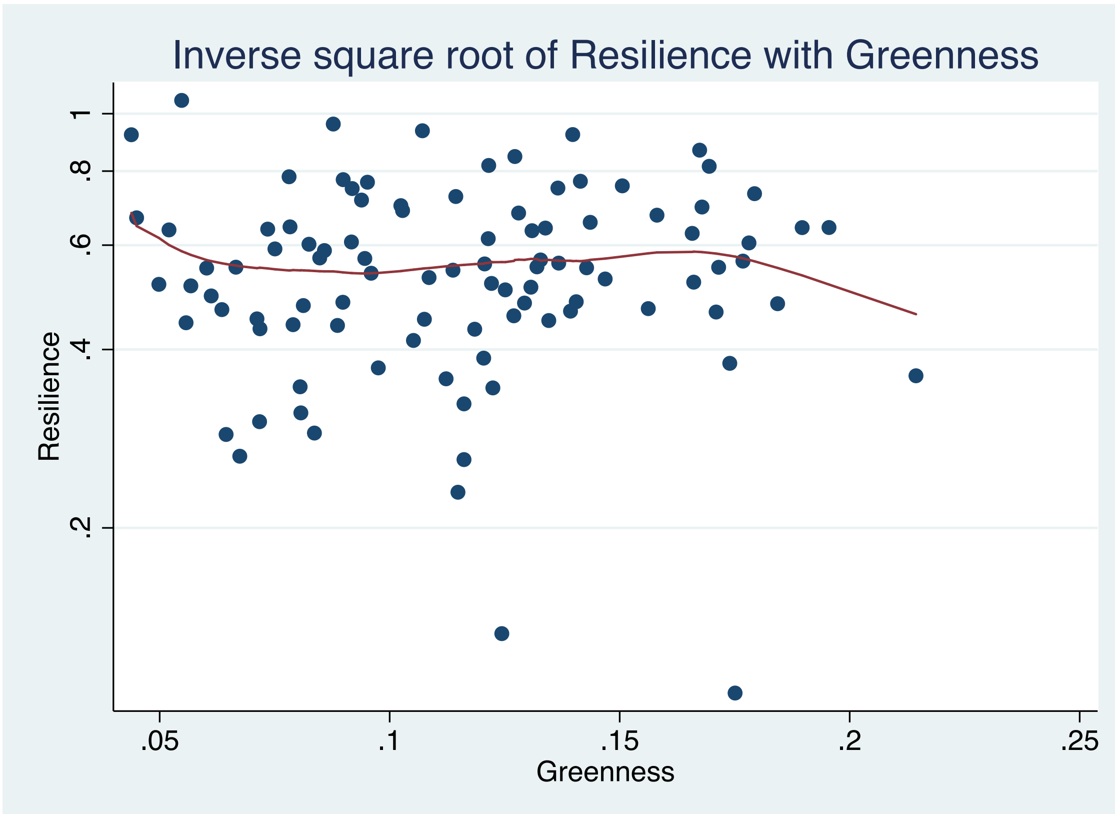


Figure 21

Unsupported mediation of greenness with resilience by crime

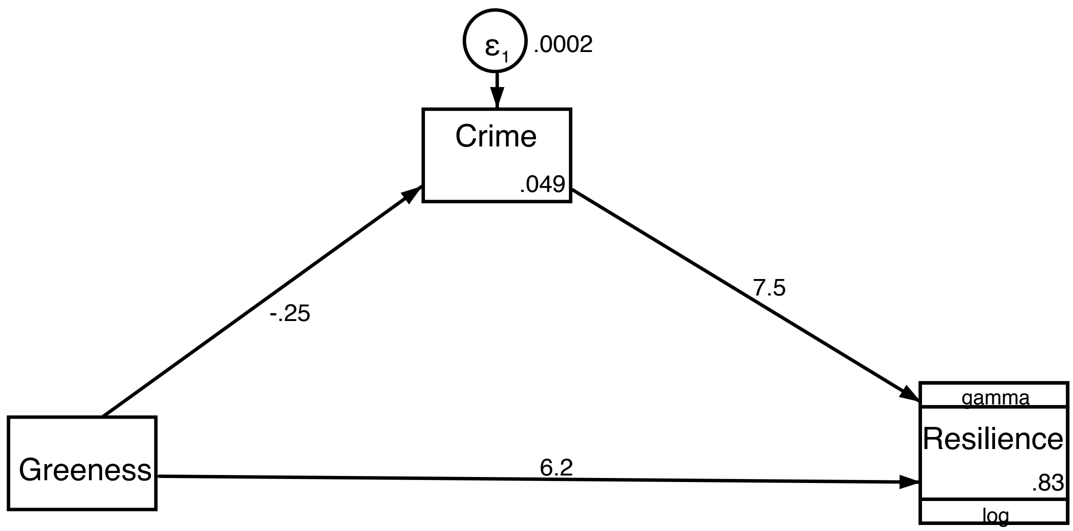


Figure 22
Comparison of slopes between unexposed, exposed as adults only, and adult plus child.

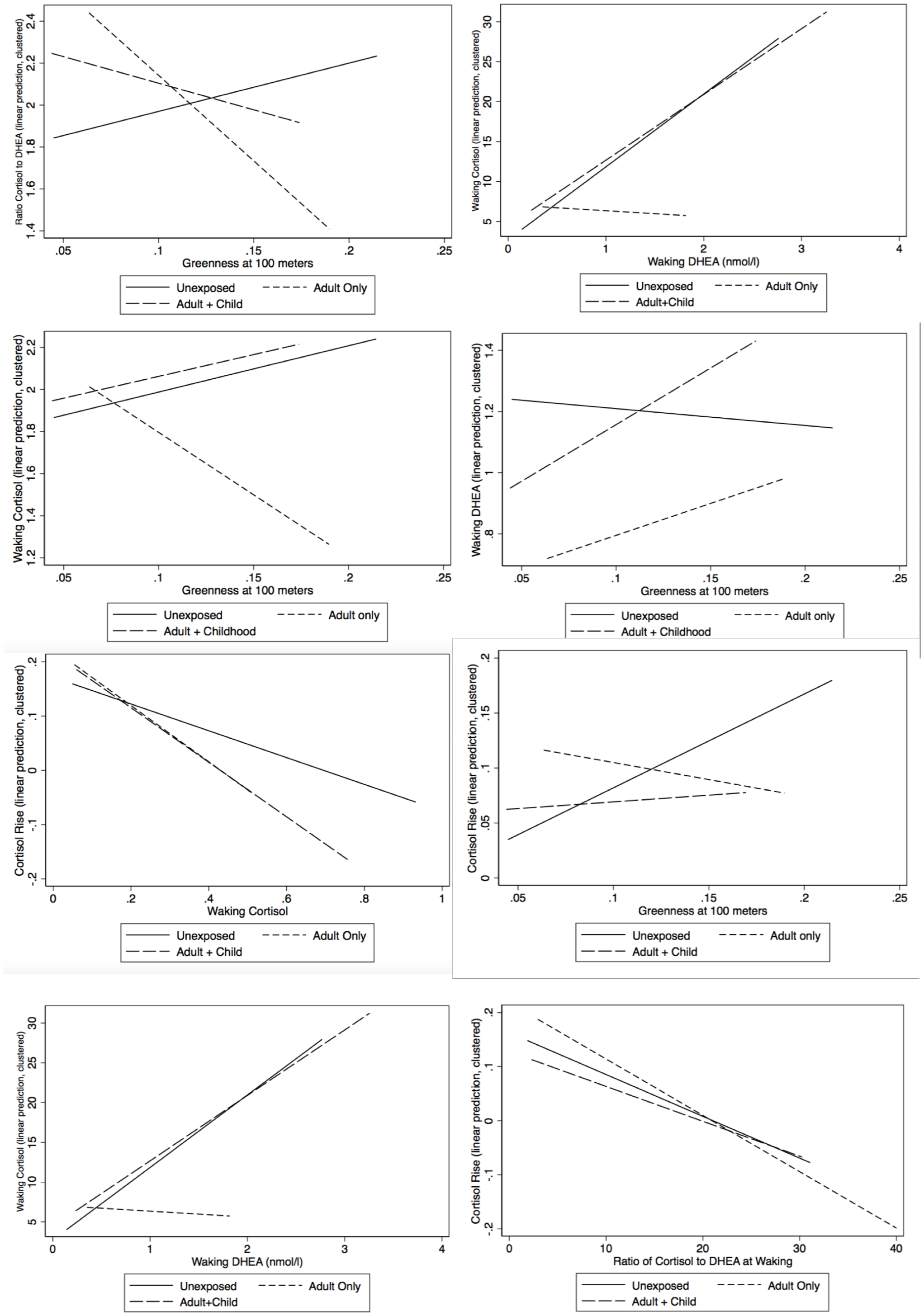
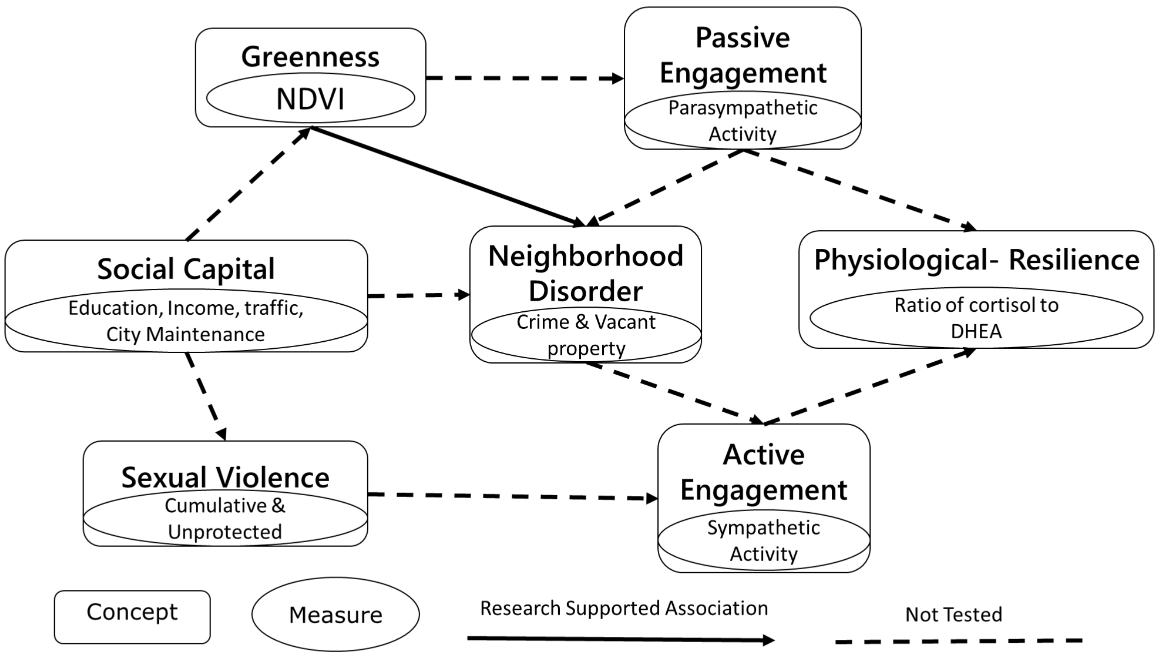


Figure 23

Re-conceptualized model of greenness, cumulative sexual violence, social capital and physiological resilience



APPENDIX A: In-depth interviews with women who experienced sexual violence (ESSENCE Study)

1. ENVIRONMENT

Warm up: I would like to have you think about your current living environment and neighborhood.

Q1a. How would you describe your current environment and neighborhood?

Probe: **feelings of safety**.

Probe: **street harassment.**

Probe: **neighborhood vacancies/abandoned buildings/vandalism.**

Probe: **crime/illegal activity.**

Probe: **neighborhood violence.**

Probe: **police activity/presence.**

Q1b. [Include questions from Participant Profile]

Warm up: I would like you to think about gardens, parks and other green spaces with trees or other plants.

Q1c. Please describe the green spaces where you live.

Probe: How do you feel when you are in or see green space?

Probe: If you were to go to a green space, who would you meet?

Q1d. What would you change about the green spaces where you live?

2. LIVING SITUATION

Warm up: I have a good understanding of your living environment and neighborhood. Now I would like to understand your current living situation.

Q2a. How you would describe your living arrangements?

Probe: **feelings of safety**.

Q2b. Can you tell me about the people who you primarily live with?

Probe: **relationship(s).**

Probe: **feelings of safety.**

Probe: **risky behavior** (i.e. drug use, alcohol use, sexual behaviors, trading/selling sex).

Q2c. [Include questions from Participant Profile]

<u>3. STRESS</u>

Warm up: Now let's move onto your everyday life.

Q3a. Can you discuss some of the main stressors in your life?

Probe: **school, work, and/or financial stress.**

Probe: **children, family, relationships.**

Q3b. How do you normally deal with your stress?

Probe: **risky behavior** (i.e. drugs, alcohol, risky sexual behavior, etc.)

Probe: **mental health** (i.e. behavioral changes, angry/mad, short tempered, anxious, etc.)

Q3c. Can you describe a time that you felt most frightened in your life?

Probe: **childhood abuse, IPV, physical abuse, forced sex, emotional abuse**

Probe: **neighborhood/community**

Q3d. Have you ever sought social services or psychological services for any stressful events in your life? If so, why? If not, why?

Probe: **type of services.**

Probe: **if this was helpful or harmful.**

Probe: **history of mental illness or psychological disorders.**

Q3e. [Include questions from Participant Profile]

<u>4. RELATIONSHIPS</u>

Warm up: Now let's move onto the topic of relationships and specific relationships in your life.

Q4a. Can you discuss what you feel is a positive, healthy relationship?

Probe: **current relationship.**

Probe: **current experience of abuse.**

Probe: **past relationship(s).**

Q4b. Thinking about your past relationships, how would you describe how healthy these were?

Probe: **safety concerns.**

Probe: **disrespect.**

Probe: **mistrust.**

Probe: **abuse history.**

Q4c. [Include questions from Participant Profile]

<u>5. VIOLENCE</u>

Warm up: Now we will be moving onto times in your life that you experienced traumatic events.

Q5a. Can you describe an event in your life that you would describe as traumatic for you?

Probe: **current abuse.**

Probe: **past experiences with witnessing violence, childhood abuse, IPV, physical abuse, forced sex, sexual violence, and/or psychological/emotional abuse.**

Q5b. [Include questions from Participant Profile]

Cool down: Thank you very much for sharing those experiences with me.

<u>6. SERVICES/IMPROVEMENT</u>

Warm up: Now I would like for you to think about all that we have discussed today.

Q6a. In all that you experienced, what are the experiences or services you wish could have been available to you as you lived through that experience?

Probe: **social services.**

Probe: **medical services.**

Probe: **police.**

Probe: **relationships.**

Probe: **community organizations**

Probe: **church**

Q6c. What wish do you have for yourself in the future?

Probe: **resilience.**

Probe: **future goals.**

CLOSING: Is there anything else you think we should know about your experiences?

APPENDIX B: In-depth interview with key informants representing communities with high and low levels of greenness

1. **<u>GREEN SPACE</u>**

Warm up: I would like you to think about the parks, gardens and other green spaces in your neighborhood.

Q1. How would you describe the current green spaces in your neighborhood?

Probe: **Gardens**

Probe: **Wooded areas**

Probe: **Street trees and yards**

Probe: **Flower pots and planters**

2. **<u>NEIGHBORHOOD HISTORY</u>**

Warm up: I would like you think about how your neighborhood have changed over the years.

Q2a. What changes have you seen to the green space in your neighborhood?

Probe: **city budgeting**

Q2b. What events happened that influenced the changes in green space?

Probe: **civil unrest**

3. **<u>GREEN SPACE ACTIVITY</u>**

Warm up: I would like you to think about the people and green spaces in your neighborhood.

Q3a. Who do you see in green spaces in your neighborhood?

Probe: **Individuals**

Probe: **Groups**

Probe: **Youths**

Probe: **Families**

Q3b. What kind of activities do people do in your green spaces in your neighborhood?

Probe: **Recreation** (do you or others play sports for fun)

Probe: **Relaxation** (enjoyment)

4. ACCESS TO GREEN SPACE

Warm up: I want you to think about visiting green spaces in your neighborhood

Q4a. What makes it difficult for people to be in green spaces in your neighborhood?

Probe: **Maintenance**

Probe: **People**

Probe: **Traffic patterns**

Q4b. What helps people to be in green spaces in your neighborhood?

Probe: **Quality**

Probe: **People**

Probe: **Sidewalks**

Q4c. Who takes care of green spaces in your neighborhood?

Probe: **Individuals**

Probe: **Organizations**

Probe: **City government**

Probe: **Church**

5. IMPACT OF GREEN SPACE

Q5a. How do people in your neighborhood see the green spaces as influencing health

Probe: **Physical activity**

Probe: **Recreation**

Probe: **Relaxation**

Q5b. Does the green space in your neighborhood influence the behavior of people in your neighborhood?

Probe: **Aggression**

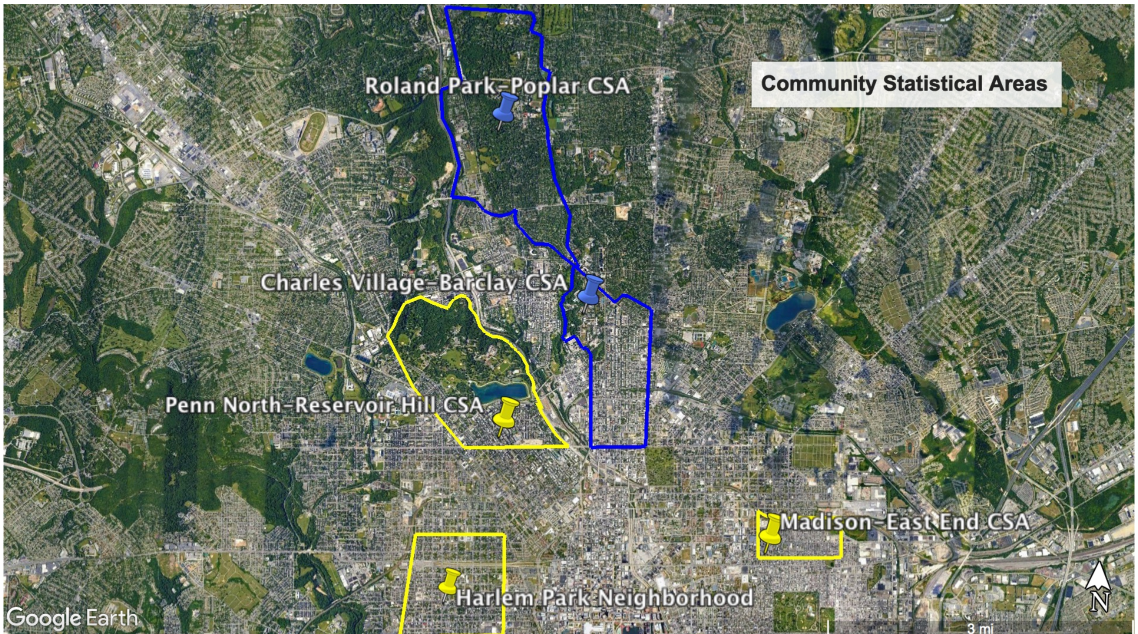
APPENDIX C: Glossary of Terms

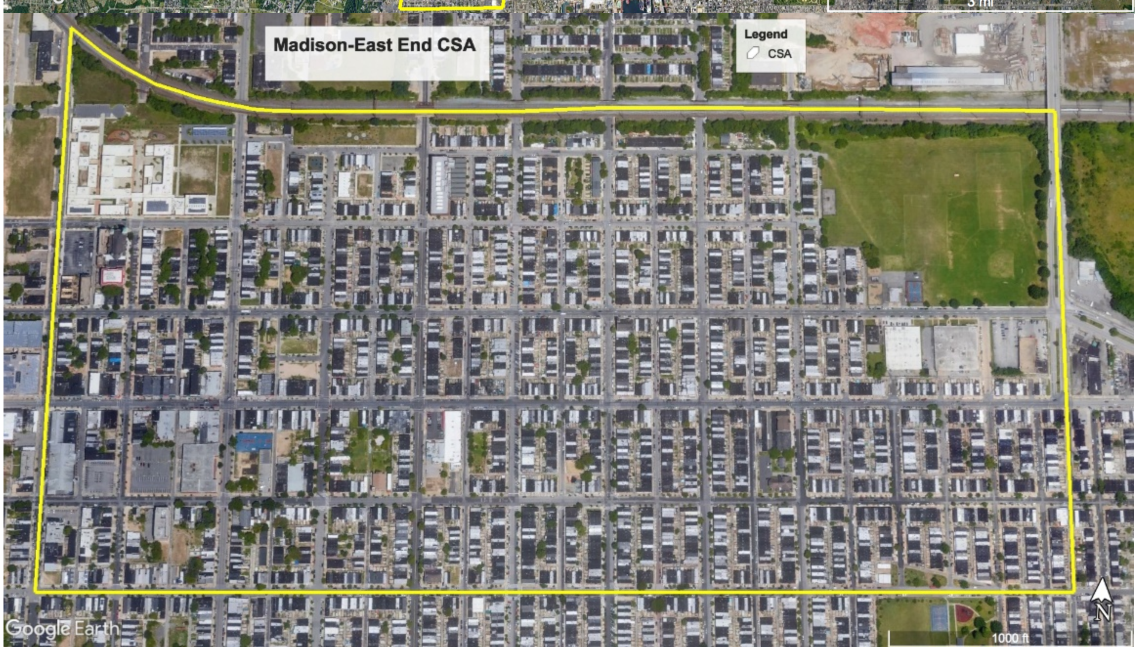
β	BETA
BNIA	Baltimore Neighborhood Indicators Alliance
C	Celsius
CDC	Centers for Disease Control
CI	Confidence Interval
CO_2	Carbon Dioxide
CSA	Community Statistical Area
CSV	Comma Separated Value
DBF	Data Based File
DHEA	Dehydroepiandrosterone
DHEA-S	Dehydroepiandrosterone-Sulfate
EI	"Exposed" informant
ELISA	Enzyme-Linked Immunoassay
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HPA	Hypothyroid-pituitary-Adrenal
HIV	Human Immunodeficiency Virus
HOLC	Home Owners Loan Corporation
KI	Key Informant
Km2	Kilometers squared
M-EE CSA	Madison-East End CSA
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
Nmol/L	Nanomoles per Liter
PN-RH CSA	Penn North-Reservoir Hill Community Statistical Area
RED	Visible Red
SD	Standard Deviation
US	United States
USGS	United States Geographic Survey
WHO	World Health Organization

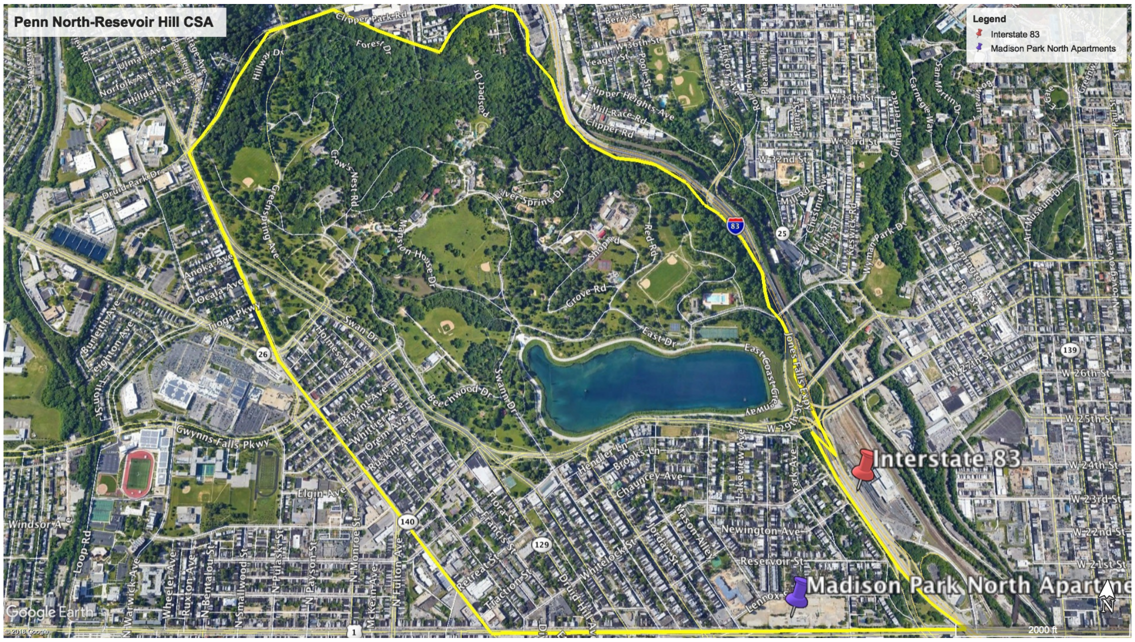
APPENDIX D: “The highway to Nowhere” (Google Inc, 2017; Gillispie, 2018)

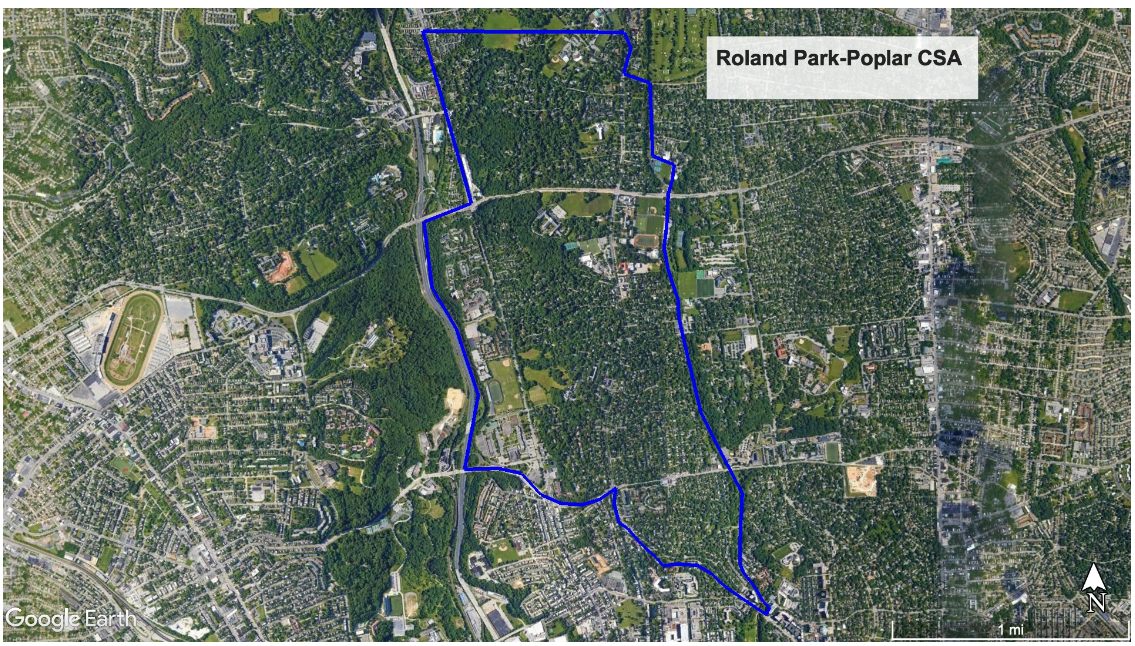
APPENDIX E: View of "Canyon" from Arlington Street Overpass (Google Inc, 2017)

APPENDIX F: Baltimore's CSA: overview and individual CSA






Penn North-Resevoir Hill CSA
Legend
Interstate 83
Madison Park North Apartments
Interstate 83
Google Earth
2000 ft


Roland Park-Poplar CSA
Google Earth
1 mi
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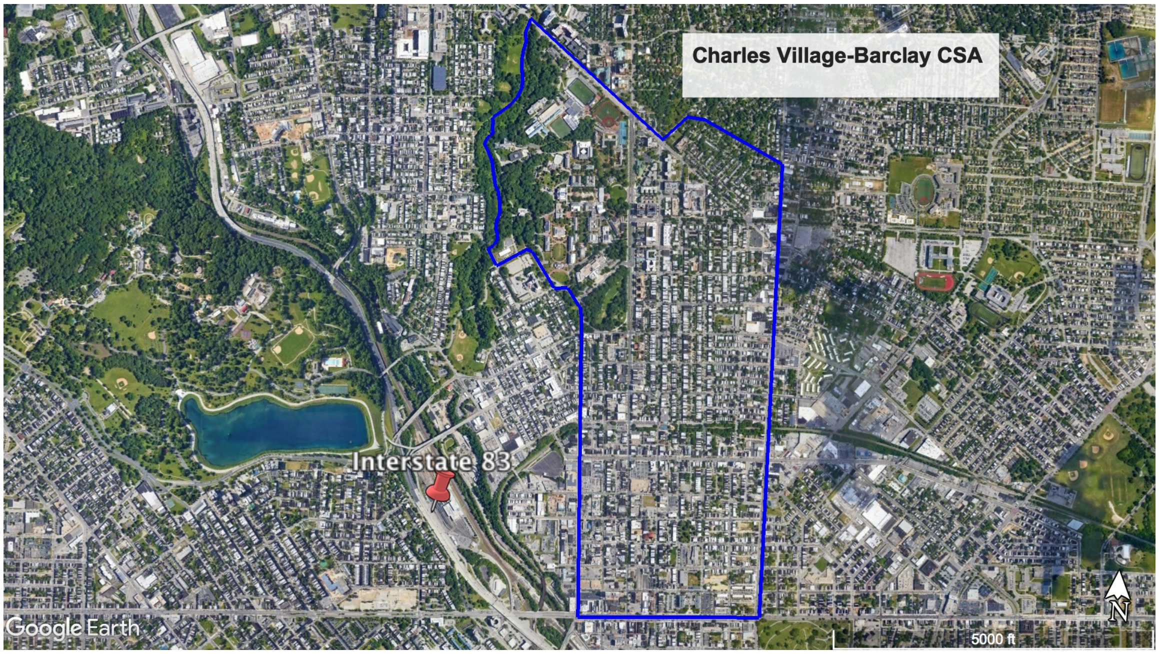
Charles Village-Barclay CSA
Interstate 83
Google Earth
5000 ft
N

APPEXDIX G: Madeira Street Central Block Park (Google Inc, 2017)

APPENDIX H

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EDUCATION

PhD	Johns Hopkins School of Nursing, Final Oral Exam August 15th, 2018
MSN-Ed	Daemen College, 2013
BSN	University of Nebraska, 2010

CURRENT LICENSE AND CERTICIATION

Year	Source, Type	License Number	Expiration Date	
2014	Registered Nurse NY	692527	January	2020
2011	Registered Nurse NE	70688	October	2018
2003	Basic Life Support		August	2019

PROFESSIONAL EXPERIENCE

2017	Clinical Instructor, Johns Hopkins School of Nursing, Department of Community/Public Health
2016-present	Assistant Coordinator, Johns Hopkins School of Nursing, Peace Corps Coverdell Fellowship program
2015	Adjunct Faculty, Pacific College of Oriental Medicine, Nursing Program
2011-2013	Health Care Adviser United States Peace Corps; USAID & Malawi Ministry of Health Program: Integrated (HIV Effect) Mitigation and Positive Action for Community Transformation, Zomba District, Malawi.
2010	Adult Psychiatric Nurse, Richard Young Hospital, Kearney, NE.

HONORS AND AWARDS

2015	Excellence in Advanced Nursing Practice Award, Daemen College

2015 Inducted into Sigma Theta Tau International: Pi Zeta, Daemen College

RESEARCH SUPPORT

2017-2018 Principal Investigator, “Greenness and Resilience in the Urban Environment” Ellen Levi Zamoiski Doctoral Fellowship

PUBLICATIONS

Peer Reviewed Journal Articles

Mancus, G. & Campbell, J.C. (2018). Integrative review of the intersection of green-space and neighborhood violence. *Journal of Nursing Scholarship*. 50(2), 117-125. https://doi.org/10.1111/jnu.12365

Fernandes, M., & Mancus, G. (2018) Three Chinese Medicine Interventions Used in the Treatment of Pediatric Asthma: An Investigation of Clinical Trials. *Journal of Acupuncture and Oriental Medicine*. 5(2) https://www.meridiansjaom.com/vol-5-no-2.html

In Preparation

Mancus, G., Cimino, A., Campbell, J.C., Winch, P., Szanton. S., Han, H., Sharps, P., & Hanson, G., Gunderson, K., & Stockman, J., Greenness and the resilient potential: barriers and facilitators. Target Journal: *Journal of Interpersonal Violence.*

Mancus, G., Hasan, MD.Z., Cimino, A., Campbell, J.C., Szanton. S., Xue, Q., Hanson, G., Stockman, J., & Tsuyuki, K. Relationship of green space and physiological resilience among urban dwelling African American women at high risk of HIV, within the built and social environment. Target Journal: *Journal of Planetary Health*

Mancus, G., Tsuyuki, K., Cimino, A., Campbell, J.C., Stockman, J. & Gundersen, K. Spatial analysis of factors of the built environment and sexual violence among black women at high risk for HIV/STI. Target Journal: *Journal of the Association of Nurses in AIDS Care.*

Mancus, G. & Cimino, A. Spatial association of neighborhood violent crime, experience of abuse and depression. Target Journal: *American Journal of Public Health.* Cimino, A. & Mancus, G. Neighborhood disorder and cortisol levels. Target Journal: *Journal of Molecular Biomarkers and Diagnosis.*

Peer-Reviewed Oral Presentations

Mancus, G., Tsuyuki, K., Cimino, A., Campbell, J.C., Stockman, J. & Gundersen, K. (2017, October). *Spatial analysis of factors of the built environment and sexual violence among black women at high risk for HIV/STI.* National Conference on Health and Domestic Violence, San Francisco, CA.

Other

Cimino, A. & Mancus, G. (2017) White paper – Spatial level HIV risk in Baltimore City, Maryland. Presented to Baltimore City Health Department

TEACHING

Johns Hopkins University School of Nursing

Clinical Instructor, **Public Health Nursing**- 2 credit, master entry in nursing, 8 students (Fall 2017)
Teaching Assistant, **The Research Process and Its Application to Evidence Based Practice**- 3 credit, master entry in nursing, 72 students (Summer 2017)
Teaching Assistant, **The Research Process and Its Application to Evidence, Based Practice**-3 credit, master entry in nursing, 72 students (Summer 2016)

Pacific College of Oriental Medicine

Course Developer and Lecturer, **Issues and Trends in Nursing and Healthcare**- 3 credit Hybrid, Bachelors level, 10 students (Summer 2015)
Lecturer, **Community Nursing/Population Focused Healthcare**- 3 credit, Bachelors level 10 students (Spring 2015)
Clinical Instructor, **Community Nursing/Population Focused Healthcare**- 1 credit, Bachelors level, 10 students (Spring 2015)

Niagara University

Teaching Assistant, **Nursing in Community Health**- 3 credit, Bachelors level, 20 students (Fall 2013)

RESEARCH EXPERIENCE

2017-2018 Research Assistant, Auricular Point Acupressure: Examining the scientific underpinnings of pain relief. (PI: Chao Hsing Yeh, Johns Hopkins School of Nursing).
2015-2018 Research Assistant, Physiological and behavioral mechanism linking forced sex to HIV risk NIH R01HD077891. (PI: Jamila Stockman, Site PI Jaquelyn Campbell, Johns Hopkins School of Nursing).
2016 Research Assistant, Integrating Social Science and Systems Methodologies for Sustainability: Promoting Appropriate Waste Disposal Practices in Low-income Neighborhoods NSF SMA-1416873. (PI: Peter Winch, Johns Hopkins School of Public Health).

ACADEMIC SERVICE

Library Committee, Daemen College, 2013-2015
Curriculum Committee, Niagara University, Nursing Program, 2013
Promotions Committee, Pacific College of Oriental Medicine, 2015

SELECTED PROFESSIONAL TRAINING

Climate changes health: CDC BRACE (Building Resilience Against Climate Effects), 16 September 2015
Danger Assessment for Intimate Partner Homicide, Johns Hopkins School of Nursing, 17 October, 2015
Design and Analysis for Developing and Validating Measurement Tools, 2 November 2015
Implementation Science: The Signature Science of Global Health, Consortium of Universities for Global Health, 7 April 2017
Methods in Using NASA Remote Sensing for Health Applications, 20 April 2017
Fundamentals of Remote Sensing (NASA), 21 April 2017
Building the Resilience of Coastal Communities in the Face of Climate Change, Planetary Health Alliance, 29 April 2017
Gender Based Violence and HIV: New Strategies to address the intersection in community and healthcare settings to reduce inequities among black women, National Conference on Health and Domestic Violence, 26 September 2017

PROFESSIONAL ASSOICATOINS

American Nurses Association, 2007-present
American Public Health Association, Climate and Health Working Group, 2013-present
Sigma Theta Tau International, 2015-present
Alliance of Nurses for Health Environments 2015-present
Global Health Council, 2013- 2014
American Holistic Nursing Association, 2007-2015